OPTIMAL FARM ORGANIZATION FOR THE CERRADO REGION OF BRAZIL

BY

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A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL
OF THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1981

This dissertation is dedicated to
my wife ZARA, to my sons ALEXANDRE
and RICARDO, and to my daughter
CRISTINE, with gratitude for their
love, understanding and encouragement
during the entire program.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude and appreciation to Dr. Gerald O. Mott, chairman of the supervisory committee, for his continuous support, guidance, teaching and criticism throughout the graduate program and on this work.

Appreciation is also expressed to Dr. Don D. Hargrove, Dr. Ramon C. Littell, Dr. Darell E. McCloud and Dr. Bryan E. Melton for serving as members of the supervisory committee. Special thanks and appreciation are extended to Dr. W. Arden Colette for substituting for Dr. B. E. Melton and for his valuable help in setting the model, and to Dr. Robert S. Kalmbacher for substituting for Dr. D. E. McCloud.

Thanks are extended to graduate student Ciro Davila for the suggestions and help in building the computer model, to Meg Niederhafer for editing and to Maria I. Cruz for her help, friendship and for typing this dissertation.

Thanks to Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) for the financial support and to Centro de Pesquisa Agropecuária (CPAC) for the data provided.

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Abstract of Dissertation Presented to the Graduate Council
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

OPTIMAL FARM ORGANIZATION FOR THE CERRADO REGION OF BRAZIL

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December, 1981

Chairman: Gerald O. Mott
Major Department: Agronomy

Linear programming was used to develop a profit-maximization model for determining optimal levels of field crops, forages, supplements and beef cattle enterprises for the *cerrado* region of Brazil.

Cerrado represents 20% of Brazil's surface area (approximately 180 million ha), supports 36% of the cattle herd, and contributes significantly to the country's rice, corn and bean production. Extensive cow-calf operations are typical of this region, with low productivity resulting from seasonal forage production. Little improvement can be expected unless supplementation is used during the dry season.

This study was developed upon the hypothesis that the herd's nutrient requirements could be met with forage supplementation systems. Cattle alternatives included selling steers at varying ages and at different calving rates.

Forage alternatives included range, improved range, several cultivated forage species, levels of N fertilization, mixed pastures, deferred grazing, hay-making and irrigation.

Supplementation alternatives investigated were urea, molasses, cottonseed meal, soybean meal, hay, sugarcane, corn, cassava leaves and roots, irrigated pastures and crop residues.

Cash crop alternatives were rice, corn, beans, soybeans, wheat and cassava roots.

Deferred Brachiaria improved pasture, colonialgrass without N, hay, leucaena, sugarcane, cassava aerial parts and roots, and rice-pasture association appeared frequently in optimal solutions.

Concentrate, urea and molasses were supplemental feed sources used. Energy intake was the factor limiting animal production in all solutions.

Crops in the optimal solutions included beans, soybeans, cassava and wheat.

Liveweight sales/ha increased as the area of cultivated pastures increased. Maximum net returns were obtained as liveweight sales increased from 14 to 179 kg/ha subsequent to increasing either calving rates or selling ages of steers. Maximum net returns were obtained when between 1 and 10% of the land was sown to cultivated pastures. More intensive systems required activities that were both more productive and more costly. Herds with lower calving rates required larger areas of range per AU.

A sensitivity analysis indicated the most sensitive activities in each system.

CHAPTER I

INTRODUCTION

In recent years agricultural scientists throughout the world have begun to explore the potential value of the tropics as food-producing areas. The tropics comprise 38% of the earth's land surface, approximately 5 billion ha; 45% of the world's population, about 1.8 billion people, live there, according to estimates made in 1975. The natural vegetation of different areas in the tropics is related to climate; savannas and other grasslands cover 43% of the tropics (Sanchez, 1976).

According to Ferri (1977), the term savanna is used to designate plant communities characterized by the continuous herbaceous strata that covers the soil in conjunction with a discontinuous strata comprised of shrubs and trees. The savannas in Brazil are called _cerrado_. Four types of _cerrado_ were defined using a gradient of biomass as the differentiating feature (Ferri, 1977). The _cerrado_ area as a specific region within Brazil is still not well delimited, and estimates of its size are speculative. Fundação Instituto Brasileiro de Geografia e Estatística (FIBGE) (1979) estimated that more than 175 million ha—or about 20% of Brazil's land area—are covered by _cerrados_. The region is important as the site of 36% of the Brazilian cattle herd. The main crops cultivated in the _cerrado_ are rice, corn and beans; cotton, cassava, sugarcane and soybeans are grown but are of less importance.

The economies of most tropical countries are based on agriculture. Food supply is becoming critical in the tropics, especially in the aftermath of the world energy crisis. The rate of population growth is greater in the tropics than elsewhere, and food production is not increasing at a comparable pace. According to Instituto Brasileiro de Geografia e Estatística (IBGE) (1978), in the period between 1960 and 1970 the rural population of the *cerrado* grew by 33%, whereas the Brazilian population grew by only 8%. In the 1970's the population growth in the *cerrado* is estimated to have been even higher as it became possible to utilize the land more fully.

In the *cerrado*, as in other tropical areas, crop yields, food and energy production can be drastically increased by the application of presently known technology (Goedert et al., 1980). It is estimated that 50 million ha of *cerrado* land are suitable for crops; in addition, 80 million ha can be used by livestock, and 20 million ha are appropriate for timber production.

Converting the *cerrado* region into productive land area still depends upon better knowledge of the different ecosystems within the region. The identification of the geographical area of the *cerrados* and the different ecosystems within it in order to identify factors that either limit or encourage agriculture is at the initial stage. In their first approximation Azevedo and Caser (1980) identified 40 subregions in the *cerrado*. Azevedo (1979) divided Goiás State into 11 zones or geosystems from which priority areas should be selected for more intensive work and possible locations of research institutions.

The traditional farming system in the cerrado is an extensive cow-calf operation. Governmental incentives to develop this area resulted in a large influx of people from southern and souteastern Brazil, bringing with them technological improvements and capital. Land is abundant and cheap, but additional investment is necessary. As natural grasslands are transformed into cropland and cultivated pastures, research must provide guidelines for their rational economic development.

In the cerrado, forages are usually the only feed consumed by cattle. One of the most serious problems facing farmers and ranchers is the fluctuating supply of feed throughout the year. Feed is available in excess during the wet season but is in short supply during the dry season.

The nutritional requirements of the herd should be met, but doing so is complex as no single solution is adequate. The best answer in most cases requires a combination of approaches. A beef production system based on grasslands only can be satisfactory, as long as forage conservation programs, fodder material and/or concentrates are used to fulfill the animals' nutritional requirements. Cultivated pastures, which usually require fertilizers, increase forage production during the wet season with little effect in the dry season. Using fertilizer alone often is not adequate. Frequently forage supplies are more fully utilized when combined with forage conservation programs, such as haymaking or deferred grazing. Feeding concentrate to some categories of animals might also be advantageous, but the form and level are often not known.

Once the yearly feed supply has been increased and more evenly distributed, more animals are usually needed in the system to convert this added food into additional production. Saturnino et al. (1977), using simulation to transform rangelands into cultivated pastures, found a dramatic increase in the number of animals in the herd and in weight sold, without modifying the area used.

Aside from traditional animal production in the _cerrado_, many immigrant farmers are also beginning to increase crop production. They would like to know which cultivated crops would be most profitable and what portion of farm resources should be allocated to this activity.

Suggestions regarding optimal farm organization for the cerrado region of Brazil will be developed in this study, using a fixed land area and varying the calving rate of the breeding herd. Linear programming was the analytical tool used to develop these various farming systems.

Several reasons can be elucidated as justification for this study. First, the _cerrado_ region is considered the best alternative for agricultural expansion. Second, large sums of money are allocated for development of this area by the government, and research projects are well funded. Third, the region already has a fairly good infrastructure. The transportation system within the _cerrado_ region is improving. Access to and from other developed centers of the nation is adequate, and storage facilities in some areas are sufficient. Fourth, the region, with approximately 10 million inhabitants is an important center of consumption. Last, farmers with good managerial abilities will probably be able to immediately apply recommendations resulting from this study.

Adopting better production alternatives will not only increase farmers' net incomes, it will also immediately increase food production to help meet the expanding demands of the rapidly growing population in the cerrado region. In consequence, new jobs will be generated and the economy and society will benefit.

In addition to the immediate effects that a study of this nature can have on production, it also might be helpful in establishing priorities for future research. Given the energy crisis, knowing to which areas or problems scarce resources might best be applied is important. This study might help in the selection of future research efforts in order that the largest impact may be achieved within the shortest period of time. A systems approach, such as this, identifies those components that should go into farming systems. It then becomes the responsibility of local investigators to research specific components of the systems rather than dedicating their limited time and efforts to alternatives which may not be as relevant at present. An interdisciplinary research team is very beneficial and important in systems. Producers are generally better served by information and recommendations generated from an overall systems analysis of problems.

Objectives of the Study

The overall objective of this study was to learn possible uses of linear programming in solving more complex problems associated with agricultural systems. An evaluation of a limited number of potential alternative farming systems for the cerrado region of Brazil was performed using this technique. The immediate objective was to determine the nature of enterprise organization that will maximize net farm income in a fixed land area, given specific limited farm resources. This was achieved in the following ways. First, net returns were maximized by selling culled bulls, culled cows, heifers not used in the replacement process, and steers at various ages; implicit is the understanding that herd requirements were provided for during the entire year. A second means of maximizing net returns involved adding cash crops to the systems. This information should serve the useful purposes of establishing priorities for future research in the region and of providing guidelines to farmers who must choose between alternative production opportunities. Although the information generated will not be directly applicable to any single farming situation, it will not be difficult to make adjustments in the set of restrictive resources so that they apply to a specific farm, thus giving results for that particular set of circumstances.

Analysis of alternative farming systems should provide information for the rational utilization of cerrado-area resources, especially the native pastures, which once destroyed can never be recovered. The native pastures have been neglected, although they still contribute significantly to beef production. Popular opinion tends to underestimate their value as farmers and researchers think about their destruction and replacement with species which are not as well adapted, often less durable and higher in cost. Identification of areas which could support improved or cultivated pastures is of considerable interest to progressive farmers of the region who wish to better utilize the available resources.

Previous Research

The methods used to evaluate farming systems in the tropics have been quite varied. The technique of surveying is frequently used. For example, Centro Internacional de Agricultura Tropical (CIAT) is evaluating the prevailing beef production systems of the Colombian and Venezuelan llanos and the cerrado of Brazil in technological and economic terms. Data from the first phase are presented in the CIAT Annual Reports (CIAT 1978, 1979).

Dow (1971) and Saturnino et al. (1977) used the technique of budgeting to develop and compare alternative livestock production systems in the tropics. This approach has several advantages: it can be done by hand, is simple to use and is easy to interpret. The disadvantage lies in the fact that it limits the analysis of more complex systems in which a large number of alternatives are usually inherent regarding beef production.

Linear programming has been used extensively in recent years for selecting an "optimal" production strategy from a large number of alternatives. Beneke and Winterboer (1973) outlined the different uses of linear programming in agriculture to solve problems associated with (1) maximizing profits in cases where intermediate products, purchasing and selling activities are involved, (2) minimizing problems related to ration formulation, and (3) determining optimal levels of livestock production and optimal mixes of feed ingredients necessary to meet the nutritional needs of livestock.

Connolly (1974) used linear programming to assess the optimal carrying capacity of range under single or common use, subject to constraints on the level of utilization of forage plants. The hypothesis was that common use of range by different types of animals, such as cattle and sheep, may be more efficient than separate grazing by each type. The animals may be complementary in their utilization of forage. The problem was established in terms of total forage consumed and forage consumed by each animal.

A linear-programming analysis was also used by Woodworth (1973) to incorporate differences in the growth rates of steer and heifer calves on two ranges with different costs to find the optimal allocation of calves. He found that the proposed allocation would have resulted in an increase of more than 4% in profitability over that achieved by random allocation of the steer and heifer calves.

Linear programming can also be applied to range cattle operations as long as adequate data regarding forage, animals and different types of land are involved. Weitkamp et al. (1980) developed a model which includes a variety of land-resource types and management alternatives such as would be appropriate for California annual-range ranches. They compared the effects of four forage production levels on ranch income by optimizing cattle numbers. The income above variable costs ranged from $19,607 to $84,006, and the cows numbered between 150 and 723 within a year. Since this fluctuation is not practical, they fixed the number at 300, as appropriate for a year when forage production was only fair. The extra forage in good production years was grazed by native and purchased steers. In years of poor production supplemental feed was given to the extra cows. In this situation ranch income above variable costs ranged from $5,548 to $79,193, depending on forage production. With such a tool the rancher can rapidly analyze his situation and make decisions when faced with many different management alternatives.

Forage production is seasonal. Any livestock program which relies on forage as the sole source of feed will establish the year-round stocking rate based upon the limited availability of forage during some parts of the year. An optimal livestock program depends in part upon the quantity, quality and timing of forage availability. The most profitable forage system, and hence livestock program and stocking rate, also depends upon livestock prices and costs of production inputs.

To select the optimal grazing system, Whitson and Kay (1978) used linear programming to perform an economic analysis of alternative forage systems and stocking rates for two areas of Texas. When livestock prices ranged between \$0.26 and \$0.41 per pound, the stocking rate changed from 10.3 acres/animal unit to 3.2 acres/animal unit in the Texas rolling-plains model. The livestock operation becomes more intensified as the establishment of kleingrass and lovegrass becomes economically feasible due to increasing calf prices. In the east-Texas model, when the land area was held constant and calf prices increased, more land was used for higher-cost but higher-yielding forages. This allowed a higher stocking rate in response to the higher calf prices. The results obtained by the authors illustrate the sensitivity of forage-livestock systems to changing prices. They also pointed out some difficulties in building forage-livestock models. Many managerial considerations are difficult to quantify and include in a model, and management may be the decisive factor regarding the decision to accept and to use a recommended system. The major problem areas encountered were: (1) lack of adequately defined forage-production function; (2) aspects related to forage quality; (3) livestock requirements. It may be important to handle cows and calves separately in supplemental feeding programs.

The applications of using supplements in meat production are receiving increased attention due to continuous price changes. Fulfilling animal nutrient requirements is a major economic consideration in any modern livestock enterprise because of the high costs of feed supplements. Usually beef cow herds obtain most of their nutrients from forages; determining least-cost rations has received less attention in commercial cow-calf operations than in any other type of livestock enterprise. Melton (1978), using linear programming, illustrated the economic importance of nutrient recommendations and supplemental feeding by determining the least-cost supplemental rations for four hypothetical Florida cow herds. They were assumed to be identical with respect to size, age of cows and calving rates, and each herd received equal nutrients from grazing. He first calculated the cows' requirement in dry matter (DM), metabolizable energy (ME) and digestible protein (DP) on a monthly basis, with corrections for different ages, weights, breeding or genetic potentials, physiological conditions and environment. A set of feedstuffs including costs and nutrient concentration and the herd nutrient requirements were then used to obtain the least-cost ration. Supplemental feed costs were found to range between 40 and 50% of the variable costs per kg of calf weaned. Purchasing or feeding more than what is required can be economically disastrous.

On the other hand, if herd nutrient requirements are not met, production can be affected and equally disastrous results engendered. Accurate appraisal of animal nutrient requirements and subsequent determination of economically optimal rations were concluded to be of obvious economic importance in modern beef herd management in Florida.

A dynamic linear programming model was developed by Melton et al. (n.d.) to evaluate alternative improved grasses for use in tropical cow-calf production systems typical of southern Florida. The objective of the model was to determine minimum costs necessary for meeting the nutrient requirements of a given herd of cows; cultivated pastures were used in combination with native range and certain raised and purchased supplements within a fixed land resource. Monthly productions of the forages were obtained from clipping studies. The cummulative production not consumed in a period was carried-over and was assumed to decline in nutritive value by 40% per month during the warm season and 60% per month during the cool season. Results of the analyses indicated that least-cost systems for tropical cow-calf production could be expected to include a combination of several improved grasses and range. For a fixed land area, average costs per cow may be expected to increase significantly as herd size is expanded. This indicates the fallacy of increased herd sizes and output per hectare as a means of increasing producer's profits. The authors also called attention to assumptions made regarding the decline in quality of forage carried-over, animal consumption and use of clipping data; these assumptions should be questioned and are areas for further research.

Prevatt (1979) developed a profit-maximizing dynamic linear programming model to determine the optimal levels of field crops, forage and beef cattle enterprises for northern and western Florida. The optimal solution included several crops and forage activities. Tobacco and peanuts were produced at their allotted levels, while corn and soybean acreage varied over the 5-year planning horizon with product prices. Also the levels of forage varied over the 5 years due to the variations in field-crop and cattle activity levels. The beef cattle herd included calves, yearlings and cows of all ages. The size and the structure of the herd changed dramatically with variations in cattle prices. Annual profits ranged from $12,190 (when all yearling heifers were retained and both field crop and beef cattle prices were low) to $71,342 (when field crop prices were high and many beef cattle were liquidated). The total revenues from field crops were consistently greater than beef cattle revenues. The author called attention to the limitations imposed by the model, while recognizing its many potential uses.

The use of linear programming in tropical South America to optimize enterprise combinations for farms where cattle, forages and crops are involved has been rather limited. The main restriction to its utilization has possibly been the lack of computer facilities. This situation is changing as more people use this tool to analyze complex problems in farm planning. Timm (1972) and Villasmil et al. (1975) used linear programming to develop farming systems for a particular area in Venezuela. The former considered various cattle, forage, concentrate and cash crop alternatives in his study. Provisions were made for changes in the quantity and quality of forage during the different periods of the year. The coefficients used were determined through the aid of surveys, area studies, and interviews with competent individuals in the area. Fertilization of pastures with urea, making hay two times during the year, and making forage sorghum silage were the forage alternatives that consistently appeared in the more intensive systems. The production and sale of fresh cassava roots and hay were the cash crop alternatives that appeared in these systems. Alternatives related to cattle showed dairying to be much more profitable than fattening purchased bulls. The profit obtained by selling bull calves was inversely related to milk production levels. In all cases additional cows were needed to fully utilize the feed that was produced. The study indicated that it would be highly profitable for farmers to put as much as 25% of their land under cultivation.

On the other side, Villasmill et al. (1975) focused their study on the development of optimal systems for the production of milk, with beef as a secondary product, via more efficient forage production and conservation. Two dairy cattle and one beef-fattening operation were considered. Four nitrogen programs and three forage-conservation alternatives were considered. The purchase of additional cows was also included as an alternative in the model. The restricted resource was capital availability. The results indicated that no nitrogen should be applied when costs exceeded 26 cents/kg. By increasing the price of nitrogen from 13 cents to 26 cents/kg, the number of fattening steers decreased from 529 to 375 and the fertilized pasture decreased from 277 to 0 ha. Net income was decreased by more than $7,000. Purchasing additional cows did not enter into the optimal plans. The inclusion of resource restrictions, such as capital, gives more realistic and applicable results.

In Brazil, Grawunder and Mielitz Netto (1979) applied linear programming to a problem of profit maximization by changing calving rates, slaughtering age and mating age of heifers in a traditional beef-production system from Rio Grande do Sul. This system was based on utilizing native range. To achieve the proposed changes, they incorporated supplements and winter-cultivated pastures to the model. They concluded that cattle production was insufficiently lucrative even under extremely favorable conditions. It could not compete with agriculture for land use. If cattle production should be developed in this area, priority must be given to increasing calving rate.

Oliveira et al. (1975) stated that the cerrado can be viewed as an area where resources are not well used due to the interaction of several economic and social factors. If it is possible to modify these factors, traditional utilization of the cerrado can be improved. Using linear programming, they developed alternative farming systems with the goal of maximizing profits. Various cattle and cash-crop alternatives that use modern technology were added to the traditional systems of six subregions of the cerrado. Restrictions were imposed on various resources including land, labor, machinery use, capital, pastures or crop area. In every case but one, net return was higher from the proposed optimal solution than from the traditional system. The authors concluded from their study that the potential exists for viable and possibly superior agricultural systems for all subregions and sizes of farm analyzed. It seems that with the expectation of increased demand for agricultural products, the agricultural productivity of the cerrado will be very important. The organization of the enterprises varied within the different subregions and according to farm sizes. Beef production appeared less competitive than the crop activities; it rarely was included in the optimal solutions. When beef production did figure, the size of the herd was drastically reduced. Upland rice was the only crop to appear in most solutions. Labor was the most restrictive resource. The authors suggested that better information on returns from cattle production is required. Their study unfortunately did not reflect on the important fact that cattle production is the main activity in the _cerrado_ and is of greater importance than agriculture.

Hoeflich et al. (1977) applied linear programming to a profit maximization problem in which different crop rotations were studied for two _cerrado_ counties of Goiás State. All rotations began with rice and were put into pasture for the 4th year of rotation. The farm area was 500 ha. If no restrictions were imposed regarding capital and labor, all 500 ha were used in the following sequence: rice, corn, corn and pasture. When restrictions were imposed, the same sequence still appeared in the optimal solutions, but with less land under cultivation. The optimal solutions were very sensitive to changes in prices. When the price of rice increased by 4.5%, achieving the same net return required 114 ha of land under cultivation with the sequence of rice, rice, rice and pasture, and 371 ha under cultivation in the order of rice, rice, corn and pasture. To better evaluate the effects of prices, productivity and input costs on net return, 100 combinations of sequences were generated at random. The results indicated that corn, rice and soybeans gave negative returns respectively in 10, 23 and 32% of the cases. According to the authors the changes in the prices of products affect farmers, and this accounts for either the rapid adoption of a new crop or its failure to come into cultivation.

Monteiro et al. (1981) used computer simulation to determine the impact of the introduction of improved pasture on the bioeconomic efficiency of a traditional cow-calf system; they also estimated how changes in herd management would interact with systems emphasizing improved pastures. The management strategies included purchase of old cows for fattening, increased size of herd, age and weight of steers at time of sale, and changes in both calving rate and age of first calving. The results suggested that investing in cultivated pasture in order to increase the productivity of traditional ranches selling weaned calves can only be recommended for a maximum of 5% of the total farm area. When 40% of the land was sown to cultivated pasture, the economic investment was unsound, even when breeding, rearing and fattening were part of the system. The economic outcome became very attractive when old cows purchased for fattening were brought into the system. A 10% increase in calving rate was equivalent to reducing the age of first calving to three years. Research efforts should be concentrated on calving rate since it can be raised by more than 10%. As the breeding phase does not seem to warrant investment in cultivated pastures, the authors believe that increased calf production will come from horizontal expansion into new areas of cheaper land, unless cheap methods are found for increasing the productivity of the native range.

Description of the Study Area

The cerrados occur mainly in the central western region of Brazil, between 20° and 5° south latitude and 42° and 55° south longitude (Fig. 1). They also extend into parts of the northern, northeastern and southeastern regions. About 73% of the region is located in the states of Goiás, Mato Grosso and Minas Gerais. The approximate distribution of the cerrado area is presented in Table 1. It is estimated that about 50 million ha are arable and that there is enough water to irrigate 10 million of these hectares. In both ecological and socioeconomic terms, however, this region is heterogeneous and great care must be taken in extrapolating research data.

It is necessary to better understand differences that exist in the ecosystems of this region if research work on priority areas is to be successfully carried out and subsequently utilized. The cerrado region brings together a series of favorable characteristics making it especially suitable for crops, cattle and forestry. A brief report on some of these aspects follows.

Climate

The climatic conditions in the cerrado are very favorable for agriculture. Solar radiation is high with a daily mean of 364 cal/cm^2, according to Centro de Pesquisa Agropecuária dos Cerrados (CPAC) (1978). The average minimum temperature of 14°C and average maximum of 27°C permits agricultural development without the limitation of frost. Total rainfall per year according to Azevedo (1970) ranges between 1200 and 1700 mm. The main problem is distribution since 90% of the total precipitation falls between September and April. The winter dry season

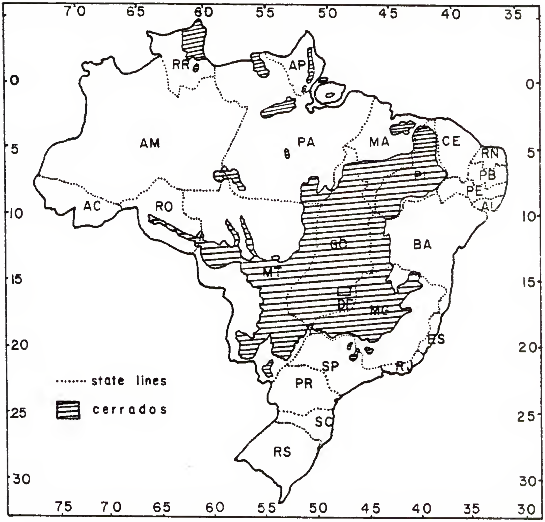

Fig. 1. Known areas of cerrado including transitional areas bordering formations.

Source: CPAC. 1976.

Table 1. Approximate distribution of the _cerrado_ area within Brazil.

States	_cerrado_ area km^2	Percentage
Goiás	555,000	88
Mato Grosso	479,000	39
Minas Gerais	308,000	53
Maranhão	98,000	30
Piauí	115,000	46
Bahia	105,000	19
Distrito Federal	6,000	100
Others	17,000	--
Total	1,830,000	

Source: CPAC, 1976.

seriously limits efforts to improve production of beef cattle. Figure 2 indicates how forage production follows the rainfall pattern. The axis representing monthly rainfall is comprised of means calculated from data taken over 40 years at Formosa, Gioás State (CPAC, 1976). The dry season occurs from May through September. Little precipitation falls during this period. Although extensive rainfall occurs during the rainy season, variable periods without precipitation frequently occur. These are called veranicos; they can be critical for both crop and forage production. Production of dry matter is adequate during the rainy season, especially for cultivated pastures. The low carrying capacity of the cerrado is imposed by the diminishing growth during the dry season. Forage left over from the rainy season may be high, but the quality is so poor that it is barely eaten by cattle during the dry season. Figure 3 shows estimated metabolizable energy produced and the requirements of two different types of cows. Fulfilling cattle requirements can only be accomplished by schemes that entail some kind of supplementation. Surplus guineagrass dry matter (and consequently metabolizable energy and digestible protein) produced during the rainy season, if not properly stored, contributes little to the nutritional requirements of cattle during the dry season.

Soils

Table 2 shows an approximate distribution of major soils units in the cerrado. The Latosols (Oxisols), with Yellow Red and Dark Red types predominating, are most important and comprise about 52% of the cerrado. They are deep, highly-weathered soils of low natural fertility. The level of aluminum saturation is high, while phosphorus

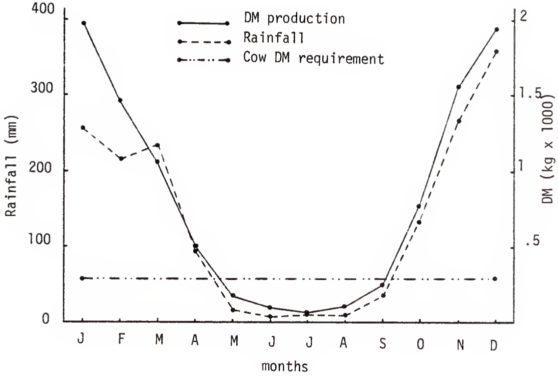

Fig. 2. Typical monthly rainfall in the cerrado, guineagrass dry matter (DM) production per ha and cow dry matter requirements.

Sources: CPAC, 1976
Pedreira, J.V.S., 1973
Melton, B. E., 1978.

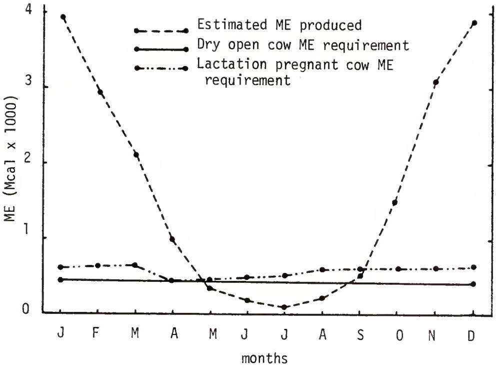

Fig. 3. Estimates on a monthly basis of the metabolizable energy (ME) produced per ha of guineagrass pasture, and ME requirements of two categories of cow.

Sources: Melton, B. E., 1978.
ME based on data from Pedreira, J.V.S., 1973, assuming 2% ME in DM.

Table 2. Approximate distribution of the most extensive soil units of the continuous area of the *cerrados* in relation to the soil taxonomy and the Brazilian system.

Brazilian system	Order	Soil Taxonomy Great Group	Total area	Cerrado
			millions of ha	%
Latossolos	Oxisols			
Latossolo Vermelho Amarelo		Acrustox	69.7	41
Latossolo Vermelho Escuro		Haplustox	17.9	11
Latossolo Roxo		Haplustox	6.9	4
			94.5	56
Areias Quartzosas	Entisols	Quartzipsamments	34.3	20
Laterita Hidromórfica	Ultisols	Plinthaquults	17.0	10
Podzólico Vermelho-Amarelo Distrófico		Ustults	2.1	1
			19.1	11
Podzólico Vermelho-Amarelo equiv. Eutrófico	Alfisols	Ustalfs	7.0	4
Litossolos		Lithic groups	15.1	9
Total			170.0	100

Source: Sánchez et al., 1974.

levels are very low; these soils strongly fix phosphorus into non-available forms.

Quartz Sands (Entisols) occupy some 20% of the area; derived from sandy sediments, they are of very low natural fertility.

Ground Water Laterites (Ultisols) have very poor drainage during the rainy season. They also have low natural fertility, but not as low as the Oxisols and Quartz Sands.

The fertile Red Yellow Eutrophic Podzolic soils (Alfisols) are high in base saturation but comprise only about 6% of the total area of the *cerrados*.

The Lithosols are shallow soils associated with rocks; they are generally of low fertility and have serious physical and chemical limitations.

The physical characteristics of *cerrado*-area soils are usually good. They are deep and quite permeable, with favorable topography which makes them appropriate for year-round mechanization.

In Table 3 are presented data from chemical analyses of 528 top-soil samples from the central area of the *cerrado*. The majority of the soils analyzed show levels of pH (H_2O) below 5.0. More than 90% of the samples had contents of calcium, magnesium, phosphorus, potassium and zinc less than the suggested critical level. About 92% of the samples had Al saturation levels above 20%, the level at which crop yields diminish.

Forage Resources

The main activity in the *cerrado* region is beef cattle production on range pasture and some introduced forages. The most important

Table 3. Relationship between the native vegetation in the center of the Brazilian cerrados and topsoil characteristics found in 538 soil samples.

Soil characteristics	Physiognomic type of vegetation				Semideciduous forest
	Campo limpo	Campo sujo	Cerrado	Cerradao	
	(64)*	(148)	(225)	(45)	(16)
pH (H O)	4.87	4.94	5.00	5.14	5.28
OM (%)	2.21	2.33	2.35	2.32	3.12
Exchangeable Ca (meq/100 g)	0.20	0.33	0.45	0.69	1.50
Exchangeable Mg (meq/100 g)	0.06	0.13	0.21	0.38	0.55
Exchangeable K (meq/100 g)	0.08	0.10	0.11	0.13	0.17
Exchangeable Al (meq/100 g)	0.74	0.63	0.68	0.61	0.78
Effective CEC (meq/100 g)	1.08	1.19	1.43	1.81	3.00
Al Saturation (%)	69	58.	54.	44.	40.
Available P (ppm)**	0.50	0.5	0.9	2.1	1.4
Available Zn (ppm)**	0.5	0.6	0.6	0.6	1.1
Available Cu (ppm)**	0.6	0.7	0.9	1.3	0.9
Available Mn (ppm)**	5.4	10.3	15.9	22.9	24.1
Available Fe (ppm)**	35.7	33.9	33.0	27.1	37.2
Clay (%)	33	36	34	32	37
Silt (%)	20	16	15	16	16
Sands (%)	46	48	51	53	47

* Number of samples taken ** Extracted by HCl 0.05 N + H_2SO_4 0.025N Source: Lopes and Cox, 1977.

advantage of this area for grazing may be the relatively large number of grasses and legumes that are well adapted to this ecosystem. The native forage resources of the *cerrado* are still not well known due to the size of the region and the large number of species present. Besides grasses and legumes, many tree-like species also serve as browse, especially during the dry season, according to Medina (1976) and Simão Neto (1976).

Many grass and legume species which tolerate high Al levels and low soil fertility have evolved in this acid-soil environment. Under good management, they are capable of producing fair- to good-quality forage during the rainy season. The principal native genera are: (1) Grasses: *Andropogon*, *Aristida*, *Axonopus*, *Ctenium*, *Eragrostis*, *Mesosetum*, *Panicum*, *Paspalum*, *Pennisetum*, *Setaria*, *Trachypogon* and *Tristachya*. (2) Legumes: *Stylosanthes*, *Desmodium*, *Zornia*, *Cassia*, *Aeschynomene*, *Indigofera*, *Galactia*, *Crotalaria*, *Arachis*, *Bauhinia* and *Centrosema*. For more details see Heringer et al. (1977), CPAC (1978) and Simão Neto (1976).

Under the range conditions and low stocking rates common in the region, forage is more than ample during the rainy season, a pattern similar to that of guineagrass production presented in Fig. 2. In the dry season sufficient forage is likewise available but the quality is very low, thus limiting consumption. The content of protein in grasses often limits their suitability as forage during this period, and legumes are so sparse as to contribute little protein to the cattle's diet. Milford and Haydock (1965) found that the content of crude protein in forage from subtropical pastures must be at least 7.2% to ensure a zero nitrogen balance. The required percentage of protein is lower for Zebu cattle, however. All species studied were able to meet maintenance and some production requirements for the first 40-60 days of growth. With advancing age, however, crude-protein content decreased with large differences appearing among the grasses. Uneaten forage in the *cerrado* is usually burned at the end of the dry season, forcing premature regrowth, which is of high quality but of low availability, thereby precluding good results from this practice. Used strategically, fire can be an important management strategy in natural grasslands; it can also, however, cause the destruction of high quality species which are not fire-resistant—for example, the exotic invader, molasses grass, and probably some of the legumes.

No native grasses from the *cerrado* are important planted forage species. Since very limited work has been done in this area, a number of potentially useful native grasses may not yet be recognized. Exotic species which are very well adapted to these acid soils include *Hyparrhenia rufa*, *Melinis minutiflora*, *Brachiaria decumbens* and recently the introduced *Andropogon gayanus*. The first two have naturalized and spread spontaneously in the better soils. *Brachiaria decumbens* has been sown extensively in cleared areas and may be the most widely planted species. Often it is sown with upland rice as a companion crop. Besides its adaptability to the cerrado, its usefulness in companion planting accounts for the popularity of *B. decumbens* in pasture establishment.

Many legumes are native in the *cerrado* region (Heringer et al., 1977 and CPAC, 1978). Considerable research has focused on tropical legumes, since they provide a relatively inexpensive source of protein for the animal and a less expensive source of nitrogen for the associated grass. This may be the reason why the native grasses have been overlooked. In newly cleared areas or in cerrado areas that have been burned frequently and regularly, legumes may be either entirely absent or of low frequency. Mott and Popenoe (1977, p. 161) expressed their concern about the preservation of "this treasure of legume germplasm," emphasizing the importance of efforts directed toward making extensive collections.

Good management practices can improve the presence of legumes and make a significant contribution to quality forage production. Successful grass-legume mixtures, in which the legumes are often native, are found in the cerrado in better soils and where annual burning is not practiced.

Introducing selected grasses can result in increased carrying capacity and improved animal performance. Grass-legume pastures require higher levels of management, and good mixtures have been observed in the cerrado. Primo (1978) reported higher stocking rates and increased gain per ha on mixed pastures than on pure grass. He concluded that the level of animal production is dependent on the legume content of the pasture, the level of available nutrients and grazing management. Likewise, CPAC (1979) reported the advantage of mixed pastures, especially in the dry season. The proper and strategic use of cultivated pastures has increased calving rate and calves are ready to enter the reproductive process with a minimum weight of more than 300 kg at 24-27 months of age.

Cattle Herd

The presence in the cerrado of a large animal population constitutes an important resource that is already available. According to FIBGE (1979), of the almost 88 million ha that comprise the occupied agricultural area, 94% are pasture land carrying 36% of the Brazilian cattle herd. This emphasizes the economic significance of beef production in the area. The states of Minas Gerais, Mato Grosso and Goiás contain 92% of the cerrado cattle herd. In Minas Gerais the herd is dispersed throughout the state, but in the two others, it is concentrated in a few micro-regions. Beef productivity per ha varies from 16 to 33 kg in rangelands, and from 139 to 185 kg/ha in cultivated pastures, depending on the stocking rates (Saturnino et al., 1977). Net returns per ha in beef production were CR$17.93 (FIBGE, 1979) based on 1970 census data ($1.0 US = 4.6 Brazilian Cruzeiros in 1970). Saturnino et al. (1977) quoted cash return values per ha between CR$57.31 and CR$115.69 for range exploitation and between CR$25.17 and CR$226.69 for cultivated pasture system under different stocking rates (1974 values: $1.0 US = 6.79 Brazilian Cruzeiros).

A dramatic increase in beef productivity can be expected in this region if simple and economically viable solutions to problems of pasture yield during the dry season can be found, and if appropriate management strategies can be discerned and genetic improvement of the herd accomplished.

Adapted Crops

Of the 88 million ha mentioned previously (FIBGE, 1979) only 6% are used in crop production. This figure does not represent the real situation, considering that more than 17 million ha were incorporated into the agricultural land base between 1970 and 1975.

The most important crop is upland rice, which was restricted to forest cultivated land. It is very important in cerrado systems, since it is used as a pioneer crop. After the cerrado vegetation is cleared, rice is planted for one, two or three years; then pastures are sown. Frequently rice is used as a companion crop with Brachiaria species to establish pastures (Kornelius et al., 1979). Almost 50% of the total area cropped with rice in Brazil is found in the cerrado, accounting for approximately 40% of the national production.

Corn is the second most important crop. While part of the production is shipped to the southeastern region, it is also an important subsistence crop, in addition to its utilization as feed for the swine herd. Of the total Brazilian corn acreage only 18% is grown in the cerrado, accounting for 15% of the national production.

While the total area devoted to the cultivation of beans is not so great as for corn and rice, such production is of great significance because of the importance of beans in the diet of the Brazilian people. Of the total national area cultivated in beans, 20% is in the cerrado. The production from this region represents 18% of the national crop.

Occupying smaller areas in cultivation are cotton, cassava and sugarcane. The last two are receiving much more emphasis as a result of the energy crisis, given the possibility of producing alcohol from these crops. All three are well adapted to the cerrado environment. Soybeans and coffee, crops that were recently introduced after short testing periods, are growing in popularity. Others, like wheat, potatoes, peanuts, sorghum, banana and citrus have not yet been well accepted (FIBGE, 1979 and CPAC, 1980). It seems that a large number of crops are suitable to this ecosystem, provided soil and water deficiencies are properly corrected. Temperature and solar radiation are rarely limitations of crop production in this area.

Infrastructure

The infrastructure of the *cerrado* is still deficient, despite appreciable improvements made in the last decade. The availability of inputs is still variable, and the system of storage, transport and marketing is deficient. According to FIBGE (1979), better facilities for the storage of grains are found close to centers of consumption. Beef storage facilities are incompletely utilized, which indicates poor organization. The region is extremely large and huge amounts of capital will be needed to establish an adequate infrastructure.

Rapid improvement in the infrastructure is currently taking place in the *cerrado* (FIBGE, 1979) due to the increase in population, improvement in communications and research and extension service, credit availability, increased incentives from the government and market conditions, especially for export products like beef, soybeans and coffee. The extensive grazing type of agriculture with a dominant cow-calf operation that is currently predominant in the *cerrado* may be a consequence of the limited infrastructure in conjunction with soil and water limitations. This type of exploitation is being transformed by the incorporation of annual and perennial crops. Annual crop production imposes rapid change on the infrastructure, especially regarding storage capacity and transportation. Likewise annual crops require improvements in soil fertility; this has facilitated the introduction of more productive forage species and consequently inspired more intensive cattle-production phases. Such development could provide more meat, thus better utilizing the storage capacities already present in some areas.

Perspectives

The possibility of increasing food production in tropical areas is a reality at the scientific level and a hope at governmental level. The cerrado was for a long time considered an unproductive area for agriculture. The productivity of crops and beef is low, but according to projections made by Goedert et al. (1980) and presented in Table 4, production levels can be significantly increased. Accomplishing this requires that all arable land be incorporated and that productivity be maintained, while the annual grain and timber production be drastically increased and beef production decreased since less rangeland would be available for grazing. If available technology is used to increase productivity, the annual production of grains and timber will increase significantly. Meat production would have the highest increase under situation 3, jumping from 1.2 to 8 million tons per year. Using techniques of simulation, Saturnino et al. (1977) estimated that by raising the stocking rate from 0.2 to 1.6 AU/ha through the use of cultivated pastures, the number of animals in the herd would increase by a factor of 9.1, the animals available for sale would increase by a factor of 13.7 and the liveweight sold would be augmented by a factor of 11.2, although the area remained constant. They pointed out, however, that under the price conditions at the time of the study, intensive

Table 4. Actual productivity as compared to production projected for the *cerrado* region, given the incorporation of more land into the production process and given increased productivity.

Activities	Situation 1*		Situation 2**		Situation 3***	
	Productivity	Annual production	Productivity	Annual production	Productivity	Annual production
	ha/yr	t x 10^6	ha/yr	t x 10^6	ha/yr	t x 10^6
Annual crops	1.5 t	7.5	1.5 t	75	2.5 t	125
Beef production	15 kg	2.2	15 kg	1.2 t	100 kg	8
Timber production	15 m^3	15 m^3	15 m^3	300 m^3	30 m^3	600 m^3

* *cerrado* under current exploitation, 5 million ha by crops, 144 by beef production and one by forest.

** Projected, if 50 million ha are occupied by crops, 80 by beef production and 20 by forest.

*** Same as situation 2, increasing productivity using technology already known for the area.

Source: Goedert et al., 1980 (adapted).

pasture used for beef production would be economically viable only if the stocking rate were elevated above 1.2 AU/ha.

No doubt exists regarding the potential of the cerrado region for food production. This potential can be fulfilled only when economically viable technology is available and has been transferred to farmers. Miranda (1975, p. 14), in his address at the Seminar on Potential to Increase Beef Production in Tropical America, showed the importance of livestock production in Latin America and the overall potential of the continent. He stated that

> the realization of this potential will contribute directly to agricultural development of vast areas and consequently to better nutrition for the people of the world. It is our task as researchers, extension workers, professors and other professionals to unite our efforts in order to make full use of this potential.

CHAPTER II

DATA AND ANALYTICAL PROCEDURE

In this study the production alternatives selected and the resource restrictions imposed are either in actual use or are appropriate and feasible for the cerrado area. The model is capable of incorporating many more alternatives, as this was not intended to be an exhaustive study in the subject. Beneke and Winterboer (1973, p. 4) emphasize that "the principal advantage of linear programming as a planning method is not that it leads to one foolproof plan but that it provides a means of analyzing a variety of alternative decisions."

The Actual System

Any rational farmer or rancher has profit as a main objective of his exploitation of the land. In order to achieve this objective, the best land is usually used for crop production. Infertile areas or those of lower fertility are used as rangeland for beef production.

Any particular system cannot represent the wide range of variation found in a region as heterogeneous and huge as the cerrado. In their survey Saturnino et al. (1977) found four characteristic systems in use for beef production in the cerrado; these are presented in schematic form in Fig. 4. Land utilization as pasture varies from the simplest form of grazing to a complete improved system in which the land is cleared, limed, fertilized and sown to cultivated pastures, frequently

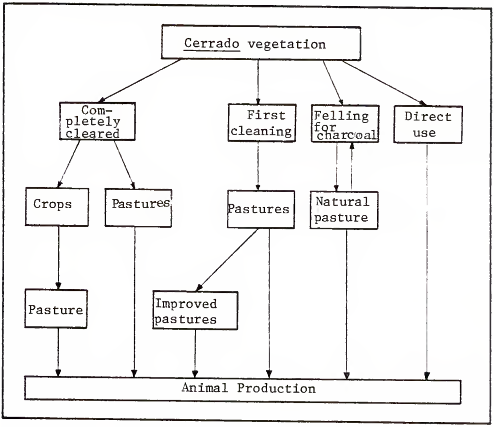

Fig. 4. Identified alternatives for exploitation of the *cerrado* for grazing.

Source: Saturnino et al., 1977.

preceded by crops. The intermediate systems are (1) cutting the cerrado vegetation for charcoal production and then using the range for grazing until a new bush canopy grows and (2) manual clearing of the vegetation on better soils after which grasses adapted to the region are introduced by top seeding without soil preparation. Some characteristics are common to all of the systems; a brief discussion follows.

Pastures

Range is the main source of animal feed. Of the 82.4 million ha in pasture land, 84% represent native range and 16% are cultivated pastures (FIBGE, 1979). Different ratios of cultivated pastures to range are common for regions within a state and between states (Saturnino et al., 1977 and CIAT, 1978).

The natural grasses are used throughout the year, with cattle being moved when the range is burned at the end of the dry season. When the rain falls, the grasses grow vigorously and are of high quality, meeting the animals' requirements for maintenance and allowing some gain. The dry matter production of native grasses follows the pattern of rainfall (Fig. 2).

Of the cultivated pastures, special reference is made to Hyparrhenia rufa and Melinis minutiflora, species which are considered naturalized because of their natural invasion and perfect adaptation to the cerrado environment. Brachiaria decumbens also has adapted very well to the acid soils and has spread rapidly because of the feasibility of sowing it with upland rice. Panicum maximum appears in some areas on more fertile soils. The cultivated pastures support higher stocking rates. They also follow the same pattern of growth presented in Fig. 2. Frequently cultivated pastures are overgrazed and used as hospital pastures to save animals from starvation in the dry season. Supplementation is rarely used in beef production in the cerrado.

Cattle Herd

The predominant breeds in the cerrado are Zebu types that lack definite characteristics, although Nellore bulls have been introduced in the states of Goiás and Mato Grosso, and Gir bulls in the state of Minas Gerais. The average performance of the beef industry in the cerrado is rather poor, as can be observed in Table 5.

At weaning time—10 months of age or older—the calves weigh approximately 135 kg. They are sold at the beginning of the dry season or when the situation on the farm becomes critical due to a lack of available feed. Cull cows are sold at 10 to 12 years of age, weighing approximately 380 kg. Culling rates range from 10 to 15%. The animals sold and slaughtered represent 14% of the cattle herd (FIBGE, 1979).

Stocking Rate

The established stocking rate in the cerrado is based on the carrying capacity of the grasslands during the dry season. It can be varied from 0.1 to 0.4 AU/ha.

Usually bulls are maintained with brood cows year-round, with the estrus period extending from September to March. Consequently, calving is concentrated in July and August. This signifies that the 5 months of higher nutrient requirements (two pre- and three post-partum) unfortunately coincide with the period of least available forage.

Table 5. Beef cattle indices in the three main states of the *cerrado* region.

Index	Minas Gerais	Goiás	Mato Grosso
Bull:cow ratio	1:50-1:30	1:50-1:30	1:30-1:15
Estrous period	Sept-Mar	Oct -Mar	Oct -Feb
Calving rate (%)	35-60	40-70	40-50
Heifer age at first calving (months)	36-60	36-48	42-54
Calving intervals (months)	16-28	16-24	24-30
Weaning (%)	32-57	35-66	35-45
Male age at slaughter (months)	38-60	42	48-54

Source: Saturnino et al., 1977 (summarized).

Because of the low quality of available forage, animals lose weight in the dry season; losses can be as great as 25% of body weight. Even under good management practices and at a stocking rate of 0.4 cows/ha, cows can loose approximately 13% of their body weight in the dry season (CPAC, 1976 and 1978). A lactating cow that is affected during the critical period of nutritional requirements is not able to reinitiate weight gain until late in the rainy season and will not become pregnant. Thus a cow may produce a calf each 20 or 24 months, with the interim period frequently being even longer.

Commonly, animals are not separated into appropriate categories. Usually ranches in the *cerrado* have few pasture subdivisions.

Labor

Often the rancher does not live on the farm. He hires a manager and cowboys at the ratio of one cowboy for 200 mating cows. Labor is of low quality. People working on the ranch perform only the basic work required, such as checking the fences and the animals, and changing pastures when fire is used in pasture management. High-quality labor will perhaps be a factor limiting the implementation of more intensive systems which require intelligent management.

Inputs

The inputs used in traditional systems are basically salt, minerals and veterinary supplies, like medicines and vaccines.

If a ranch has cultivated pastures, the rancher owns the machinery required to prepare the soil and establish the forages. Fertilizer is not commonly used.

Linear Programming

Linear programming is the most versatile of the mathematical programming procedures. Its basic concept involves the optimization of a specific linear objective function. Any problem which has three quantitative components—consisting of an objective, alternative methods or processes for obtaining the objective and resources and/or other restrictions—can always be expressed as a linear programming problem (Heady and Candler, 1958).

In this study the programming procedure was designed to give the farm plan which would maximize the objective function (net returns), given several production alternatives, subject to specific constraints. The programming matrix (appendix Table 21) consisted of an objective function, column activities, row elements, right-hand-side (RHS) constraints and resource transfer.

Resource Restrictions

Many kinds of restrictions can be imposed upon an agricultural process. Some are agronomic—for example, land utilization, irrigation, hay production, pest control. Other constraints are institutional, such as the availability of capital, supplies and services, and the accessibility and stability of markets for the products. Some restrictions are imposed by the farmer or rancher himself, like keeping a fixed number of cows or refusing to hire more than a certain number of laborers. If the chosen restrictions are well established for a particular situation, the results will reflect this wisdom. Generally, however. restrictions limit the attainment of higher income (Beneke and Winterboer, 1973).

Appendix Table 19 describes the resources and their restrictions. In this study a fixed amount of land—5000 ha— was divided into four categories: (1) rangeland, (2) improved rangeland, (3) pasture land and (4) crop land. Pasture land refers to land established with cultivated forage species.

The use of pasture land was restricted in the model with regard to some activities. Pasture established with upland rice as a companion crop was limited to 50 ha. The area allowed for grass hay production was restricted to 50 ha, and no more than 20 ha could be used for irrigated ryegrass pasture. Leucaena is not a cultivated forage in the area and therefore was limited to 125 ha.

The restrictions on dry matter (DM), metabolizable energy (ME) and digestible protein (DP) were entered in the model to insure that the minimum nutritional requirements of the beef herd were met.

When crops were used in the model, crop allotments were used to restrict the area under cultivation. Consequently, beans were restricted to 20 ha and soybeans to 250 ha.

The land used for hay production or irrigated was included in the crop land because, like crops, these activities require intelligent management. Transfer rows provide a vehicle whereby the output of one activity may be transferred in the model to another activity. Transfer rows were used to insure that no more than the amount of forage not consumed during a particular month would be carried-over to the next. The three sugarcane activities were connected by transfer rows to give the effect of a three year rotation. Hay transfer rows were used to insure that all hay produced would be consumed. Transfer rows were also used to insure crops to be used either as feed or for sale. Cattle distribution among the different categories or activities was accomplished by using transfer rows.

Production Alternatives

The cerrado region is basically a calf production area. Saturnino et al. (1977) published the following stratification of the enterprises in beef production: (1) cow-calf operation, practiced by 65% of the farms; (2) cow-calf and raising calves, practiced by 30% of the farms; (3) only 5% of the enterprises practice the whole process—calving, raising and fattening—or are only involved in raising and fattening activities. Taking into consideration the changes that are taking place in the region, fattening and crop alternatives were also considered in this study.

The selected production alternatives were divided into four broad categories: (1) forage alternatives, (2) beef cattle alternatives, (3) supplementation alternatives, and (4) cash crop alternatives.

Forage Alternatives

Forage production alternatives provide the nutritional requirements (DM, ME and DP) necessary for beef production.

Forage alternatives programmed into the model included

Range

Improved range

Leucaena

Fertilized *Brachiaria*

Deferred *Brachiaria*

Mixed pastures

Colonial grass under different levels of N fertilization

Stylosanthes pastures

Rice-pasture association

Very little information is available on the cerrado grassland yield and its real contribution to beef production. Established stocking rates for different ecosystems, even for the four main classifications, are nonexistent. What is known about this subject is based on the information obtained from ranchers. Usually the stocking rate used in the cerrado is speculative.

If no information exists on a general level, what can be said about grassland production and yield per month? What grasses, legumes and other vegetation are important components as cattle feed? How much is harvested? These aspects pose limitations for the model; they deserve considerable attention in planning future research efforts. The activities used in the model are described in appendix Table 20.

Grassland DM production values reported by Andriguetto et al. (1977) and presented in Fig. 5 were used in this study. These data are not from the cerrado. The DM production per year is much higher than the values published by Kornelius et al. (1979) and CIAT (1979). Production values are given for the different seasons and were the best available for range. It was assumed that 15% of the monthly production was consumed by cattle in the dry season, defined in this study as the period of June, July, August and September, and 25% in the other months. Digestible protein and ME in the dry matter produced were assumed to be 6.3 and 1.75%, respectively, in the dry season.

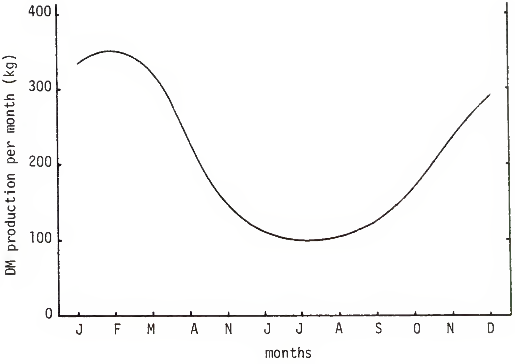

Fig. 5. Monthly estimated DM production per ha from grassland.
Source: Andriguetto et al., 1977 (adapted).

Carry-over activities were included in the model to insure that DM not consumed in one period would be available in the next one. Also, it was assumed that DM carried-over would loose 30% of its quality in the rainy season and 60% in the dry season.

By "improved range" is meant a grassland invaded by one or both of the naturalized species, M. minutiflora and H. rufa. These appear in better soils, usually when the cerrado has been hand cleaned. The former species is very well accepted by cattle and flowers in May, the end of the rainy season. It allows later utilization in a good management scheme. The second species is available for grazing earlier, is of high quality at the beginning of the rainy season, flowers in February, after which it rapidly begins to loose its nutritive value. It supports a higher stocking rate than M. minutiflora and is fire-resistant, unlike the other species which is vulnerable to the effects of burning.

Improved range production data used in this study were taken from Simão Neto (1976) and Medina (1976). Both worked with fistulated steers in order to identify the botanical composition of the diet and its quality. These data are very realistic, reflecting both the selectivity of the animals and the importance of plant species as cattle feed in the natural environment.

Calculations of DM yield were based upon animal gain; it was assumed that the percentage of the available DM consumed on a monthly basis would be: (1) for grasses, 7.5% in January through May, November and December, and 12% in June through October; (2) for shrubs and other plants, 13% in August and September and only 1% in the remaining months. Crude protein in the dry matter is high, given the nature of available forage during the dry season; this reflects the selectivity of the animals. The lowest value was 11.41% in June, and the highest was 16.25% in October. Metabolizable energy ranged from 1.69% in September to 2.81% in May. The same aspect of carry-over and loss in quality was assumed for improved rangeland in the model.

Data on cultivated pastures were obtained from several sources—Rassi (1977), CPAC (1976, 1978, 1979, 1980), Pedreira (1973), Mott et al. (1970), Quinn et al. (1961) and National Academy of Science (NAS) (1977). Leucaena is not planted in the cerrado area at present, but given its quality and production value, as well as the emphasis it is receiving worldwide, it seemed wise to include it in the model. More research on cultivated pastures is still required for the cerrado; especially needed is information on their effect on the entire system. Yields of particular species under different levels of fertilization, under different management systems, under different methods of strategic utilization, and the expected duration of the pasture should be known. In addition, the adaptation of species to the environment, their ability to persist in mixtures, their ability to shorten the critical period when forage is scarce, and their quality in the dry season are all aspects which can have great impact on beef production.

Deferred grazing is not an identificable concept for most ranchers, although they practice some kind of it. Compared with hay supplementation (CPAC, 1979), deferred grazing was found to be superior. Management of the deferred pasture is very important. The same area can be grazed during part of the rainy season or used for hay production.

Fertilization is an important matter in increasing forage quality during the dry season, gain per animal and gain per ha as Quinn et al.

(1961 and 1970) demonstrated. They also observed that N applied during the dry season appears to produce grass of more uniform quality and growth throughout the entire year. Winter N applications seem to be advantageous for earlier marketing purposes.

Prior to 1975, hay was not used in the state of Goiás. No equipment for processing hay was present in Goiás at that time. At Planaltina, CPAC began to produce and study the value of hay as an alternative for feeding cattle during the dry season. Results obtained (CPAC, 1976, 1978) showed differences attributable to several factors, such as quality of the hay, species utilized and category of animal fed. More economic information is required about the feasibility of hay utilization. The equipment is expensive, and it seems that deferred pastures may prove a better alternative. Doubtlessly some production from the rainy season must be stored in order to have better utilization of the pasture throughout the year and greater beef production.

Sugarcane was used in the model only as a forage activity. It is well adapted to the cerrado region and highly productive; however, like some cultivated forages, it requires considerable amounts of fertilizer and other inputs. Bull (1975) studying the potential of three cultivars of sugarcane, obtained from 50 to 192 tons/ha, depending on density and row spacing. In the state of São Paulo, Brazil, Ettori et al. (1968) examined a single field for three years; they mention production levels of 104, 62 and 50 tons/ha/year. Energy is an important factor affecting beef production, especially in the dry season; sugarcane could be very important, given its potential as an alternative source of supplementary energy. The harvest time is very flexible for sugarcane, since its nutritive value varies little, which is an important advantage.

Bracharia, when sown with upland rice, produces fair regrowth after rice is harvested between the middle and the end of the rainy season. This regrowth and the remaining rice straw were used as an alternative feed supply in the dry season.

Irrigation is not used in pasture production in the cerrado. Tropical and even temperate species present good growth of high quality (CPAC, 1978 and Rassi, 1977) with irrigation. Dry-period production represents between 20 and 35% of the dry matter production from the total year, the exact value depending on the species irrigated. Again, economic aspects are limitations to the adoption of irrigation practices, and more information is required on this subject.

Beef Cattle Alternatives

The following beef cattle alternatives were considered:

(1) calving rates: 50, 60, 70, 80 and 90%,

(2) selling ages of steers: 8, 20, 32 and 44 months,

(3) selling ages of heifers: 20, 32 and 44 months,

(4) culled cows, and

(5) culled bulls.

The activities selected for inclusion in this phase of the research are described in appendix Table 20. All cattle activities were organized with reference to a basic animal unit (AU) which is defined in this study as a dry open cow requiring monthly an average of 290 kg of DM, 430 Mcal of ME and 8.11 kg of DP. The establishment of this basic AU presents the advantage of permitting easy modifications in the cattle activities presented in the model or the inclusion of other activities which are important to the system. The AU requirements activity forces in the correspondent cattle activities which are components of the herd.

The following equivalencies were assumed for the different animal categories:

(1) calves equal 0.25 AU,
(2) animals from 8 to 20 months equal 0.5 AU,
(3) heifers and steers from 20 to 32 months equal 0.75 AU,
(4) heifers and steers older than 32 months equal 1.0 AU,
(5) cows equal 1.0 AU, and
(6) bulls equal 1.25 AU.

The model accounted for differences in physiological status of cows, such as pregnancy and lactation. Nutrient requirements of cows used in the model are those calculated by Melton (1978). Requirements in the other categories were calculated using National Research Council (NRC) tables (1976) with the assumptions of gains and losses presented in Table 6. Calving was assumed to occur in September and weaning in May.

Beef cattle sales activities were included in the model with the objective function being the total revenue from the production of one AU of that activity. These activities were not constrained.

It was also assumed that higher calving rates would require better management practices and produce heavier calves at weaning. This was reflected in the AU price received for calves, which was assumed to be 5 and 10% higher for the 70-80 and for the 90% calving rates,

Table 6. Gains and losses of heifers and steers during the dry and wet seasons at different calving rates.

Animals	Calving rates (%)					
	50 and 60		70 and 80		90	
	dry*	wet*	dry	wet	dry	wet
	%BW**	g/day	g/day		g/day	
Heifers	-5	400	300	500	300	600
Steers	-10	500	200	500	400	800

* dry season: June, July, August and September
wet season: remaining months

** body weight

respectively, when compared with the price of calves from the 50-60% calving rates.

The animals were assumed to have been sold at the end of the rainy season, as follows:

Calving rates (%)	Selling ages steers	heifers
50 or 60	8,20,32 and 44 months	44 months
70 or 80	8, 20 and 32 months	32 months
90	8 and 20 months	20 months

Beef production always reflects the expression of the environment, the feed supply and the genetic potential of the animals. Low calf crops, 30 to 60%, from cerrado rangelands are mainly a consequence of the low nutrition levels at which cows are raised. Energy is the single most important factor limiting high levels of reproduction in beef breeding herds (Wiltbank, 1967); this is reflected by low productivity. Reproductive efficiency seriously affects enterprise returns, and several steps should be taken at the same time to produce better results. Improving the genetic potential without improving the quality of feed may be worse than doing nothing. Improving nutrition without a cattle selection program may not give the results expected. Miskell et al. (1981) described a program in Ohio that was designed to emphasize the importance of forage and pasture improvement, along with improved beef cow-calf management. The results obtained are described by these words: "Harvest 200 dollars per acre with beef cattle from land that previously was returning no income" (Miskell et al., 1981, p. 2).

Supplementation Alternatives

Supplementation alternatives fit into two main categories:

(1) Supplements produced on the farm:

- *Brachiaria* hay
- Stylo hay
- Irrigated ryegrass
- Sugarcane
- Corn (entire plant)
- Corn (grain)
- Cassava aerial parts
- Cassava roots
- Rice straw
- Corn stubble

(2) Purchased supplements:

- Urea
- Molasses
- Soybean meal
- Cottonseed meal

Cultivation of corn and rice is becoming more common, but the fodder from these crops is seldom used. Usually the straw and stubble are burned to facilitate land preparation for the next crop. Cassava is a subsistence crop in the region. This crop presently receives government incentives when used for alcohol production. The aerial part is high in nutritive value and could be planted either as forage (Moore, 1976) or with a double purpose—utilizing the aerial parts as forage and the roots as a source of alcohol. Euclides et al. (1979) found that by mixing increasing amounts of cassava leaves with rice straw, the crude protein and lignin levels increased while fiber level decreased. Intake increased when 25% of the mixture was cassava leaves. Although some problems still exist, cassava is an alternative source of high quality feed useful in conjunction with more intensive systems in the rainy season or as supplementation in the dry season.

Sugarcane was previously mentioned. With the exception of hay, all other supplements entered the model to supply feed during the critical period extending from May through October. Hay could be used during any month of the year. Also the concentrates could be used during any month. They are very expensive but with the increase of soybean and sugarcane production in the region, more may become available, reducing relative costs.

Cash Crop Alternatives

Of regional cash crops which can be grown and later sold on the open market six of the most important were examined: rice, corn, beans, cassava, soybeans and wheat.

It was assumed that beans and cassava would be harvested by hand, the usual practice. Beans could be produced and hand-picked once or twice a year. The other crops would be harvested using combines owned by the farmer. Hiring machinery is a common practice in more densely populated areas but in more isolated communities, it can be difficult to arrange. Financing facilities for purchasing machinery have been available, but the government is changing this policy. In the future, credit will be a serious limitation in transforming the *cerrado* into the productive region proposed in some studies and established as a goal by the government program.

Considering the low precipitation in the region after April (Fig. 2), more attention and studies should be directed toward the utilization of corn for sale and the suitability of storage in the field under natural conditions, even with the ears still on the plant, for later utilization as a supplement. Vetter et al. (1970) concluded that grazing is the most economical method of using cornstalks during the winter period; no apparent effects on subsequent calving and reproductive performance were observed. They suggested corn harvest refuse as a cheap source of feed. It is, however, an expensive feed if economical methods of harvesting and storing and balanced feeding programs are not developed.

High fertilizer requirements and management practices limit corn production in the cerrado. Nevertheless, corn seems to be potentially very important as a source of feed for cattle.

Rice is grown on poorer soils, has lower fertilizer requirements and is an important pioneer crop. Soybean production is expanding rapidly in the cerrado. Soybeans are more drought-resistent than rice or corn and have better prices in the market. Wheat can be produced in the dry season with irrigation; high yields were obtained under experimental conditions (CPAC, 1980). Wheat also can be planted in late January or beginning February with fair success—possibly equivalent to that obtained in southern Brazil, a traditional wheat-producing area that experiences failures due to unfavorable climatic conditions. This alternative was examined in the model using the end of the rainy season as the planting time. The distribution of crops to be planted throughout the year is important when planning the utilization of machinery.

Production Process and Budgets

Examination of four parts of the production process is necessary in the development of budgets: (1) physical and technical production practices, (2) power and equipment costs, (3) variable costs associated with production, and (4) prices and yields of respective alternatives. Budgets were generated using the Florida Agricultural and Resource Management Systems Laboratory, or simply, "The FARM Systems Lab" (Melton, 1980).

Estimating production expenses requires knowing which factors of production need be applied, when, how often and at what rate for each enterprise. Production practices included land preparation, planting, cultivation, types and rates of fertilization, types and rates of applications of insecticides and herbicides, and harvesting. These data were used to complete a Crop Budget Preparation Form for each crop and forage situation as a step in the process of deriving the complete budget information.

In the category of power and machinery are included tractors and associated implements, trucks, self-propelled and tractor-propelled harvesting and spraying machines, and irrigation systems. Information already available in the FARM Systems Lab (Appendix V) were utilized; no modifications were introduced.

Variable costs associated with production included expenses for supplies as follows: seed, fertilizer, lime, insecticides, fungicides, herbicides, and machinery and equipment expenses, the costs of the other inputs were entered in the Crop Budget Preparation Form for each enterprise.

Product yields are determined by the production process, which in turn determines production costs. Some factors of production can be controlled; others cannot. Forages are considered intermediate products, which means they are used in the production of another product and have no market value. The price paid for the factors of production, amounts received for products, product yields and additional data necessary for the budgets of each enterprise were taken mainly from Empresa Brasileira de Assistência Técnica e Extensão Rural (EMBRATER) (1979) and Empresa de Pesquisa Agropecuária de Minas Gerais (EPAMIG) (1975). Information provided by Saturnino et al. (1977) and Comissão de Financiamento da Produção (CFP) (1977) was also used. Although all prices used in this study employ figures relevant to 1975, thus giving unrealistic values due to high inflation rates in Brazil, the learning purpose of this study is not invalidated.

Computerized budgets generated using the FARM Systems Lab provided information on gross receipts, total costs subdivided into variable and fixed costs, net returns, break-even prices, and monthly information on several aspects. For details, see Melton (1980).

Procedure of Analysis

One objective of this study was to determine the optimal allocation of farm resources among prospective farm enterprises in order to maximize net returns. The profit-maximization objective was chosen because producers' decisions are generally based on this motivation. "Net returns" in this study refers to differences between total receipts and total costs; net returns are interpreted as the returns to land, overhead, risk and management.

In order to derive the optimal farm organization, linear programming was first used to maximize net returns, basing profits on cattle enterprises in which (1) calving rates varied, (2) steers were sold at several different age levels, (3) heifers were sold when not used in the process of replacing culled cows, and (4) culled bulls and culled cows were sold.

Restrictions imposed on the resources were previously described. Costs of activities entered the objective function as negative values, while returns associated with the sale of animals were entered as positive values. No costs were associated with either carry-over activities or activities expressing nutritional requirements of the various categories of animals. For each selling age within each calving rate considered in this study, specific coefficients were used. These coefficients were obtained via a two-step process. First, herd structure for each situation was calculated according to rates listed in appendix Table 22 and presented in Tables 23, 25, 27, 29 and 31 of the appendix. Second, coefficients were generated based on the herd structure in terms of AU and AU available for sale; these coefficients are presented in the appendix, Tables 24, 26, 28, 30 and 32. The basic matrix used in this study is presented in the appendix as Table 21.

The sensitivity of the optimal solutions for enterprises raising only cattle was investigated in order to have an indication of the stability of the optimal solution in terms of cost and resource changes. The sensitivity analysis gives some indication of the magnitude of the decrease in cost that would be necessary for activities that had not entered the optimal solution to become part of it. It assists in the identification of critical coefficients. Activities that almost entered the optimal solution should be reevaluated in future research efforts. The analysis also gives some indication of the degree by which costs of activities entering the optimal solution would have to increase in order to justify replacement by some other activity. Those activities which, with slight increases in cost, would be eliminated from the optimal solution were considered to be very sensitive and less stable than those activities which would require large increases in their unit cost before being eliminated. In planning the organization of enterprises where at least a portion of the pastures are cultivated, one should look for those activities which would require a large increase in unit cost to eliminate them from the solution. These considerations add stability to the system and thus eliminate the need for future costly adjustments in the enterprise organization. Cultivated pastures, for example, have a high cost of planting and should be utilized as long as possible.

Another situation analyzed was the effects on net returns of the addition of cash crop alternatives to cattle enterprises. Cash crops like corn and cassava were allowed to be transferred and used as feed supplies.

Interpretation of results or range analysis can be verified by parametric programming, performed on any vector of the linear programming matrix. This procedure will also reveal all other activities that change in the solution.

Parametric procedures were used to verify the effects on net returns that would occur were the area in pasture land to be decreased, with a concomitant increase in the rangeland. This procedure was only used to analyze alternatives in which steers were sold at 8 and 32 months, within each calving rate. After the optimal solution was found, the range and pasture areas were fixed at that level and a stability analysis was performed.

CHAPTER III

RESULTS OF THE ANALYSES

Optimal Farm Systems Under Fixed Land Areas

Optimal solutions for the organizational structure of farm enterprises will be presented for each calving rate, first without crops, then adding them to the systems.

The activities which maximize net returns in the systems with the calving rate at 50% and with steers being sold at 8, 20, 32 and 44 months of age are shown in Table 7. Herd structure and the animals sold are presented in Table 8. All systems but one have negative returns; the deficits decrease in amounts as the ages at which steers are sold increase. These systems are not efficient due to the small calf crop (46%) (Table 8); this circumstance, in conjunction with the high cost of cultivated pastures, accounts for the fact that such systems are economically infeasible, even when the steers are retained until the age of 44 months. The reader should consider that the model was designed to fulfill the requirements of cattle. These criteria cause increased costs and hypothesize situations rarely found in actual systems in the cerrado. Ranchers whose calf crop is this low usually prefer to buy extra hectarage of range than invest in cultivated pastures. A decade ago the price of land in the cerrado region was very low. Production was not necessarily the first objective when someone bought more land in this region; frequently the purpose was price speculation (Oliveira et al., 1975). Although some speculation still exists, increased productivity has become imperative if farmers are to have economically viable systems.

With respect to the AU in these systems, more are maintained when steers are sold at 32 and 44 months. Thus it is possible in these systems to increase net returns by reducing the number of cows with a correspondent reduction in the number of animals in all other categories (Table 8). In this table it can be seen that although the number of animals sold decreased when steers were sold at older ages, the AU sold actually increased, being 42% higher when steers were sold at 44 months of age. In other words, more income was generated by the sale of older steers, even though fewer animals were involved in the sale. The increased volume of AU sold accounts for the higher income of certain of these systems.

When crops were incorporated to the systems, no significant changes occurred in either the number of AU supported or in the number of AU sold (Table 8). Net returns were positive only when steers were sold at 44 months of age. Comparing the differences in net returns with and without crops, it can be seen that the amount is almost the same for the four comparisons.

With respect to the activities that entered the optimal solutions (Table 7), leucaena was useful only in the more intensive systems—those in which steers were sold at 32 and 44 months of age. Two factors are worth considering in regard to substituting leucaena, which can be managed without nitrogen inputs, for stylo and/or colonial grass. First,

Table 7. Computer-determined alternatives maximizing net returns at different selling ages of steers, with and without crops as part of the system, under a calving rate of 50%.

Description	Without crops Selling ages (months)				With crops Selling ages (months)			
	8	20	32	44	8	20	32	44
Net return ($)	-54857	-53085	-46992	-14466	-14551	-12720	-6532	26353
AU	2707.5	2662.1	2946.1	3043.5	2753.2	2705.0	2960.8	3060.1
Rangeland (ha)	2000	2000	2000	2000	2000	2000	2000	2000
Impr. rangeland (ha)	1250	1250	1250	1250	1250	1250	1250	1250
Pasture land (ha)	1250	1250	1250	1250	1250	1250	1250	1250
-Deferred *Brachiaria*	206.6	186.7	198.8	261.4	207.3	187.1	189.9	262.1
-Yield of colonial grass (ON)	933.1	952.9	864.9	751.5	956.8	975.8	872.9	760.7
-Leucaena			125.0	125.0			125.0	125.0
-*Brachiaria* hay cut twice	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
-Stylo hay cut twice	60.3	60.4	11.3	62.1	35.9	37.1	3.3	52.2
Crop land (ha)	66.5	64.7	75.8	61.4	430.0	430.0	430.0	430.0
-Rice pasture assoc.	50.0	50.0	50.0	50.0				
-Sugarcane 1	5.5	4.9	8.6	3.8				
-Sugarcane 2	5.5	4.9	8.6	3.8				
-Sugarcane 3	5.5	4.9	8.6	3.8				
-Bean 2 crops					20.0	20.0	20.0	20.0
-Soybean					250.0	250.0	250.0	250.0
-Wheat					134.8	136.4	135.4	143.3
-Cassava					25.2	23.6	24.6	16.7
Feed								
-Total hay (t)	406.7	407.0	239.7	412.8	323.4	327.7	212.2	379.3
-Total urea (kg)	678	1035	2434	2097	798	1184		816
-Cassava roots (t)					186.8	175.4	182.7	124.2

Table 8. Herd structure and animals sold in systems with and without crops, under a calving rate of 50% and selling the steers at different ages.

	Without crops				With crops			
	Selling ages (months)				Selling ages (months)			
Description	8	20	32	44	8	20	32	44
Net return ($)	-54857	-53085	-46992	-14466	-14551	-12720	-6532	26353
AU	2707.5	2662.1	2946.1	3043.5	2753.2	2705.0	2960.8	3060.1
Total cows:	1642.2	1512.8	1534.0	1427.4	1670.0	1538.0	1540.8	1435.2
Lactating pregnant	0	0	0	0	0	0	0	0
Lactating open	821.1	756.4	767.0	713.7	835.0	769.0	770.4	717.6
Dry open	821.1	756.4	767.0	713.7	835.0	769.0	770.4	717.6
Bulls	65.7	60.5	61.3	57.1	66.8	61.5	61.6	57.4
Calves	755.5	659.9	705.3	656.5	768.2	707.1	708.8	660.1
Heifers:								
8-20 months	365.2	336.4	341.0	317.4	371.4	341.9	342.7	319.2
20-32 months	354.3	326.3	330.7	307.9	360.3	331.6	332.4	309.6
32-44 months	345.9	318.6	322.9	300.6	351.7	323.7	324.5	302.2
Steers								
8-20 months		336.4	341.0	317.4		341.9	342.7	319.2
20-32 months			330.7	307.9			332.4	309.6
32-44 months				300.6				302.2
Total number	3528.8	3586.9	3966.9	3992.8	3588.4	3645.6	3985.9	4014.7
Animals sold:								
Heifers with 44 months	148.8	137.0	138.9	129.3	151.3	139.3	139.6	130.0
Culled bulls	15.1	13.9	14.1	13.1	51.3	14.1	14.2	13.2
Culled cows	131.4	121.0	122.6	114.2	133.6	123.0	123.3	114.8
Steers 8 months old	377.7				384.1			
Steers 20 months old		336.4				341.9		
Steers 32 months old			330.7				332.4	
Steers 44 months old				300.6				302.2
Total No. sold	673.0	608.3	606.3	557.2	684.3	618.3	609.5	560.2
AU sold	393.5	443.5	527.1	560.5	396.3	450.9	529.9	563.5

the considered DM production per year was higher for leucaena than for colonial grass and stylo. Second, leucaena is a superior source of protein, energy and other nutrients (NAS, 1977 and Ferraris, 1979). The use of leucaena in beef production was reported by Addy and Thomas (1977) with respect to utilization with crop residues and by-products, and by Blunt and Jones (1977) who examined the use of leucaena in pastures under different management systems. Problems still exist in its utilization, and Jones (1979) concluded in his review that one of the major factors limiting the use of leucaena in animal production is the lack of information available regarding its contribution as a highly nutritious forage in alternative beef production systems.

The remaining activities included in the optimal solutions were about the same for each alternative. Sugarcane was the main source of energy in each system. Its potential as an animal feed in intensive systems is increasingly obvious as additional knowledge is gained regarding its nutritional value and limitations. Preston and Leng (1978a, p. 7) wrote in their review that

> without the accompanying fundamental and applied research sugarcane feeding would never have gotten beyond the stage of a promising idea, useful in emergencies as in times of feed shortage, but not really a sound basis on which to develop animal feeding systems.

More information is required before the economics of using sugarcane as feed for cattle is well understood (Preston and Leng, 1978b); many factors are involved and they vary for different regions. However, sugarcane promises to be important in terms of improved beef production in the tropics.

Of the supplemental activities considered, hay and urea were usually used during the critical period of forage availability (between May and October). Urea supplements were often required in July and August. Molasses was not, because of the use of sugarcane. Energy was usually the limiting factor, since protein was above the animals' minimum requirements except for 2 or 3 months of the dry season. The finding that ME was the most frequently deficient nutrient is in accordance with the results of research reported by Melton in 1978; he found that during the winter months in Florida deficiencies in ME were manifest in the herds studied. In the _cerrado_ no ME deficiencies characterized the period from November to January, since these are the months of peak growth, with forage high in quality and availability.

When crops were added to the systems, the most important change that occurred was the substitution of cassava for sugarcane. Cassava is an important feed in tropical regions; the aerial parts, especially the leaves, provide protein, and energy is available from the roots. Moore (1976) proposed the utilization of cassava as a forage plant which could provide a competitive source of protein for tropical beef production systems. A more complete system, using both the aerial parts and the roots, seems to be appropriate in tropical areas, since energy is also a limiting factor in animal production. Cassava is less demanding of fertilizer than sugarcane. High production can be obtained in the _cerrado_ (CPAC, 1978 and 1980). Both sugarcane and cassava present harvest problems, and economically feasible models must be identified in order for their use to be adopted on a large scale.

Beans (which are produced twice per year), soybeans and wheat were the three crops included in the optimal solutions for all systems.

Beans and soybeans were cropped in all areas allotted; the area planted in wheat varied slightly in the different systems (Table 7). Land used in rice/pasture association was not included in the optimal solutions, and the area devoted to stylo hay was reduced because of the extent to which aerial parts of cassava supplied DM.

Rice and corn, the two most important crops in the cerrado, did not enter into the optimal solutions, which is not realistic. Activities can become part of an optimal solution in any one of three ways. Increased prices for a particular product, increased productivity or decreased costs, or an interaction between cost and production factors can stimulate the inclusion of a particular activity into an optimal solution, although the percentage of increase in price per product unit must be higher than 34%. Hoeflich et al. (1977) showed that small differences in the price of rice were responsible for changes in the systems proposed.

In Table 9 are shown the optimal solutions for enterprises with a cow herd having a calving rate of 60%. The herd structure and the animals sold are presented in Table 10. The results obtained are similar with respect to the activities selected in the systems with a calving rate of 50% which have already been discussed. Reference will only be made to the important changes. As can be seen in Table 9, the net returns for all systems are negative, with the exception of the two most intensive systems when cropping is added to the enterprises. Leucaena was part of the optimal solutions for all selling ages. The value of stylo to the overall system was diminished, although it still entered the optimal solutions. In the systems where

Table 9. Computer-determined alternatives maximizing net returns at different selling ages of steers, with and without crops as part of the system under a calving rate of 60%.

Description	Without crops Selling ages (months) 8	20	32	44	With crops Selling ages (months) 8	20	32	44
Net return ($)	-44350	-43045	-36839	-2424	-3913	-2591	3721	38462
AU	3021.3	2964.8	2919.2	3121.7	3012.2	2957.8	2947.7	3072.6
Rangeland (ha)	2000	2000	2000	2000	2000	2000	2000	2000
Impr. rangeland (ha)	1250	1250	1250	1250	1250	1250	1250	1250
Pasture land (ha)	1250	1250	1250	1250	1250	1250	1250	1250
-Deferred *Brachiaria*	221.6	197.9	186.7	238.4	221.5	197.9	188.8	246.0
-Mixed pasture				39.5				15.0
-Yield of colonial grass (ON)	846.4	868.9	876.7	723.4	841.6	865.1	886.2	756.6
-Leucaena	125.0	125.0	125.0	125.0	125.0	125.0	125.0	125.0
-*Brachiaria* hay cut twice	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
-*Stylo* hay cut twice	6.9	8.2	11.7	73.8	11.8	12.0		57.4
Crop land (ha)	80.6	77.9	71.9	65.0	430.0	430.0	430.0	430.0
-Rice pasture assoc.	50.0	50.0	50.0	50.0				
-Sugarcane 1	10.2	9.3	7.3	5.0				
-Sugarcane 2	10.2	9.3	7.3	5.0				
-Sugarcane 3	10.2	9.3	7.3	5.0				
-Bean 2 crops					20.0	20.0	20.0	20.0
-Soybean					250.0	250.0	250.0	250.0
-Wheat					137.2	138.4	135.7	144.0
-Cassava					22.8	21.6	24.3	16.0
Feed								
-Total hay (t)	224.7	228.9	241.1	452.7	241.4	242.0	201.0	396.8
-Total urea (kg)	4237	3892	3317	2984			1523	1579
-Cassava roots (t)					169.1	160.3	180.1	118.6

Table 10. Herd structure and animals sold in systems with and without crops, under a calving rate of 60% and selling the steers at different ages.

Description	Without crops Selling ages (months)				With crops Selling ages (months)			
	8	20	32	44	8	20	32	44
Net return ($)	-44350	-43045	-36839	-2424	-3913	-2591	3721	38462
AU	3021.3	2964.8	2919.2	3121.7	3012.2	2957.8	2947.7	3072.6
Total cows:	1699.0	1549.7	1383.5	1320.0	1693.8	1546.0	1397.0	1299.5
Lactating pregnant	339.8	309.9	276.7	264.0	338.8	309.2	279.4	259.9
Lactating open	679.6	619.9	553.4	528.0	677.5	618.4	558.8	519.8
Dry open	679.6	619.9	553.4	528.0	677.5	618.4	558.8	519.8
Bulls	68.0	62.0	55.3	52.8	67.8	61.8	55.9	52.0
Calves	948.1	864.7	771.9	736.6	945.2	862.6	779.5	725.1
Heifers:								
8-20 months	458.7	418.2	373.4	356.3	457.3	417.3	377.0	350.8
20-32 months	446.3	407.0	363.3	346.7	444.9	406.1	366.8	341.3
32-44 months	436.3	397.9	355.3	337.3	435.0	397.0	358.7	332.1
Steers:								
8-20 months		418.2	373.4	356.3		417.3	377.0	350.8
20-32 months			363.3	346.7			366.8	341.3
32-44 months				337.3				332.1
Total number	4056.4	4117.7	4039.4	4190.0	4044.0	4108.1	4078.7	4125.0
Animals sold:								
Heifers 44 months old	179.3	163.5	146.0	139.3	178.7	163.1	147.4	137.1
Culled bulls	15.6	14.3	12.7	12.1	15.6	14.2	12.8	11.9
Culled cows	186.9	170.5	152.2	145.2	186.3	170.1	153.7	170.2
Steers 8 months old	474.0				472.6			
Steers 20 months old		418.2				417.3		
Steers 32 months old			363.3				366.8	
Steers 44 months old				373.3				332.1
Total No. sold	855.8	766.5	674.2	633.9	853.2	764.7	680.8	651.3
AU sold	504.2	560.9	586.6	637.0	502.6	559.6	592.3	654.3

the steers were sold at 44 months, mixed pasture entered the optimal solution.

Values for total AU decreased with the increase in ages of sale up to 32 months; it increased again in the system selling steers at 44 months of age (Table 10). The total number of cows decreased by some 23% in the more intensive systems, and the AU sold increased by 26 to 30%.

Activities in the optimal solutions which maximize net returns in the systems under calving rates of 70 and 80% and selling steers at 8, 20 and 32 months of age were identical to the ones for the systems derived when the calving rate was 60%. Net returns became positive in the system without crops when steers were sold at 32 months of age. When crops were part of the systems, all solutions presented positive net returns to land, overhead, risk and management (Tables 11 and 13).

Animal units was one area in which important changes occurred. In systems selling steers at 32 months of age, the increase in the amount of AU supported was at least 32 and 57% higher than at the two other selling ages which occurred under calving rates of 70 and 80% respectively (Tables 11 and 13).

In Tables 12 and 14 are presented the herd structure and the animals sold in the systems with calving rates of 70 and 80%. It is possible to observe from these tables that the number of cows decreased when steers were sold at 20 months and increased when sold at 32 months; this is the reverse of what was obtained at lower calving rates. Also the volume of AU sold increased; it was higher when steers were sold at 32 months of age.

Table 11. Computer-determined alternatives maximizing net returns at different selling ages of steers, with and without crops as part of the system, under a calving rate of 70%.

	Without crops Selling ages (months)			With crops Selling ages (months)		
	8	20	32	8	20	32
Net return ($)	-30228	-17692	8396	10258	23220	49714
AU	2771.4	2700.4	3876.2	2779.3	2811.6	3707.1
Rangeland (ha)	2000	2000	2000	2000	2000	2000
Impr. rangeland (ha)	1250	1250	1250	1250	1250	1250
Pasture land (ha)	1250	1250	1250	1250	1250	1250
-Defferred *Brachiaria*	247.6	214.2	140.6	249.8	256.1	182.0
-Mixed pasture			469.3			362.5
-Yield of colonial grass (ON)	805.8	860.7	294.5	804.6	796.7	427.7
-Leucaena	125.0	125.0	125.0	125.0	125.0	125.0
-*Brachiaria* hay cut twice	50.0	50.0	50.0	50.0	50.0	50.0
-Stylo hay cut twice	21.5		170.7	20.6	22.2	102.9
Crop land (ha)	86.6	84.2	173.6	430.0	430.0	430.0
-Rice pasture assoc.	50.0	50.0	50.0			
-Sugarcane 1	12.2	11.4	41.2			
-Sugarcane 2	12.2	11.4	41.2			
-Sugarcane 3	12.2	11.4	41.2			
-Bean 2 crops				20.0	20.0	20.0
-Soybean				250.0	250.0	250.0
-Wheat				131.5	129.9	79.8
-Cassava				28.5	30.1	80.2
Feed						
-Total hay (t)	274.5	201.0	783.4	271.2	276.6	552.2
-Total urea (kg)	6352	7180	16327	2894	5394	8425
-Cassava roots (t)				211.4	223.6	595.1

Table 12. Herd structure and animals sold in systems with and without crops, under a calving rate of 70% and selling the steers at different ages.

Description	Without crops			With crops		
	Selling ages (months)			Selling ages (months)		
	8	20	32	8	20	32
Net return ($)	-30228	-17692	8396	10258	23220	49714
AU	2771.0	2700.4	3876.2	2779.3	2811.6	3707.1
Total cows:	1711.0	1518.0	1926.6	1716.0	1580.6	1842.6
Lactating pregnant	684.4	607.2	770.6	686.4	632.2	737.0
Lactating open	513.3	455.4	578.0	514.8	474.2	552.8
Dry open	513.3	455.4	578.0	514.8	474.2	552.8
Bulls	85.6	75.9	96.3	85.8	79.0	92.1
Calves	1126.0	999.0	1267.6	1129.2	1040.0	1212.4
Heifers:						
8-20 months	545.2	483.5	613.6	546.4	503.4	586.8
20-32 months	532.3	472.3	599.1	533.8	491.7	573.0
Steers:						
8-20 months		483.5	613.6		503.4	586.8
20-32 months			599.1			573.0
Total number	4000.1	4032.2	5715.9	4011.5	4198.1	5466.7
Animals sold:						
Heifers 32 months old	224.1	198.8	252.4	224.8	207.0	241.4
Culled bulls	19.7	17.5	22.2	19.7	18.2	21.2
Culled cows	256.7	227.7	289.0	257.4	237.1	276.4
Steers 8 months old	562.9			564.5		
Steers 20 months old		483.5			503.4	
Steers 32 months old			599.1			573.0
Total No. sold	1063.4	927.5	1162.7	1066.4	965.7	1112.0
AU sold	590.1	640.4	955.4	591.8	666.8	913.7

Table 13. Computer-determined alternatives maximizing net returns at different selling ages of steers, with and without crops as part of the system, under a calving rate of 80%.

Description	Without crops Selling ages (months) 8	 20	 32	With crops Selling ages (months) 8	 20	 32
Net return ($)	-20337	-13714	16477	22101	27360	57727
AU	2706.7	2750.1	4321.8	2788.3	2778.4	4454.5
Rangeland (ha)	2000	2000	2000	2000	2000	2000
Impr. rangeland (ha)	1250	1250	1250	1250	1250	1250
Pasture land (ha)	1250	1250	1250	1250	1250	1250
-Deferred *Brachiaria*	227.1	246.2	45.2	250.5	247.4	45.8
-Mixed pasture			695.6			698.7
-Yield of colonial grass (ON)	833.9	783.3	109.5	816.9	805.5	182.8
-Leucaena	125.0	125.0	125.0	125.0	125.0	125.0
-*Brachiaria* hay cut twice	50.0	50.0	50.0	50.0	50.0	50.0
-Stylo hay cut twice	14.0	45.5	224.7	7.5	22.1	147.7
Crop land (ha)	84.8	78.5	218.6	430.0	430.0	430.0
-Rice pasture assoc.	50.0	50.0	50.0			
-Sugarcane 1	11.6	9.5	56.2			
-Sugarcane 2	11.6	9.5	56.2			
-Sugarcane 3	11.6	9.5	56.2			
-Bean 2 crops				20.0	20.0	20.0
-Soybean				250.0	250.0	250.0
-Wheat				125.0	130.1	26.6
-Cassava				34.5	29.9	133.4
Feed						
-Total hay (t)	248.8	356.3	967.9	226.7	276.5	705.1
-Total urea (kg)	6570	5901	21058	5622	6046	14855
Cassava roots (t)				256.3	221.6	990.0

Table 14. Herd structure and animals sold in systems with and without crops, under a calving rate of 80% and selling the steers at different ages.

Description	Without crops Selling ages (months) 8	 20	 32	With crops Selling ages (months) 8	 20	 32
Net return ($)	-20337	-13714	16477	22101	27360	57727
AU	2706.7	2750.2	4321.8	2788.3	2778.4	4454.5
Total cows:	1586.1	1454.6	2000.4	1634.0	1469.6	2061.9
Lactating pregnant	951.7	872.8	1200.2	980.4	881.8	1237.1
Lactating open	317.2	290.9	400.1	326.8	293.9	412.4
Dry open	317.2	290.9	400.1	326.8	293.9	412.4
Bulls	79.2	72.7	100.0	81.6	73.5	103.1
Calves	1205.0	1105.6	1520.2	1241.3	1116.9	1566.9
Heifers:						
8-20 months	583.6	535.3	736.1	601.1	540.8	758.7
20-32 months	570.9	523.7	720.1	588.1	529.1	742.2
Steers:						
8-20 months		535.3	736.1		540.8	758.7
20-32 months			720.1			742.2
Total number	4024.9	4227.3	6533.0	4146.1	4270.7	6733.7
Animals sold:						
Heifers 32 months old	253.7	174.6	240.0	261.4	176.4	247.4
Culled bulls	18.3	16.7	23.0	18.8	16.9	23.7
Culled cows	285.5	261.8	360.1	294.1	264.5	371.1
Steers 8 months old	602.7			620.9		
Steers 20 months old		535.3			540.8	
Steers 32 months old			720.1			742.2
Total No. sold	1160.2	988.4	1334.2	1195.2	998.6	1384.4
AU sold	649.3	681.3	1109.0	668.9	688.2	1143.1

With respect to the activities selected, mixed pastures entered the optimal solutions, as it did when the calving rate was 60% and steers were sold at 32 months of age (Tables 11 and 13). The deferred Brachiaria and yield of colonial grass without N decreased in area, while mixed pasture and stylo hay cut twice both increased. The mixed pasture activity had higher production costs, but it also produced more DM of better quality. Hay requirements were much higher in systems selling steers at 32 months of age. Urea requirements increased, as did those for sugarcane and cassava in order to provide the protein and energy necessary to meet the nutritional requirements of the herd.

Under a calving rate of 90% only systems selling steers at 8 and 20 months were considered. The net returns to land, overhead, risk and management are positive for all systems, with and without crops. Compared with the previous situation (80% calving rate), the AU and the activities under the more intensive systems are strikingly similar (Tables 13 and 15). The AU in systems selling steers at the time of weaning were approximately 10% higher than the volume of AU in systems selling steers at 20 months of age (Table 15). With respect to activities in the optimal solutions, the suggested area for deferred Brachiaria was low under systems in which steers were sold at 8 months of age; this activity was not included at all in the optimal solutions suggested for the more intensive systems. Yield of colonial grass without N was also awarded little or no hectarage in the optimal solutions. In contrast, mixed pasture and stylo hay cut twice increased in the area used (Table 15). More hay and urea were required to meet the higher demands presented by the large number of growing animals (Table 16) under a calving rate of 90%. Selling steers at 20 months of age in enterprises without crops proved to be the only system requiring molasses supplementation to meet the nutrient requirements of the herd. When crops were present, cassava appeared in the optimal solutions with a large area under cultivation, supplying the energy necessary to the system (Table 15).

The volume of AU sold was about the same for all systems. The increase in net returns realized by keeping steers until the age of 20 months is very significant (Table 16).

Effects of Varying Rangeland and Pasture Land Areas

Parametric procedure was used to verify the effects upon both net return and the optimal organization of enterprises when important circumstances relating to pastures and rangelands were altered. The land in pasture was fixed at 25% of the total farm area; the information generated is not applicable to any single farming situation. Each farm represents a unique situation, with the area of land devoted to cultivated pastures varying between zero and 100%. Research indicates (CIAT, 1978) that the mean is 24% in Mato Grosso State and 14% in Goiás State, but only a small number of farms were surveyed; FIBGE (1979) reports a mean of 15.8% for the *cerrado* in general. Information obtained by applying parametric procedures to data related to land allocation is very important in planning the organization of enterprises. Corrections can also be suggested for the improvement of actual farming systems in order to make them more economically productive. The

Table 15. Computer-determined alternatives maximizing net returns at different selling ages of steers, with and without crops as part of the system, under a calving rate of 90%.

Description	Without crops Selling ages (months) 8	 20	With crops Selling ages (months) 8	 20
Net return ($)	11109	24415	52823	66296
AU	4798.1	4327.9	4823.9	4425.3
Rangeland (ha)	2000	2000	2000	2000
Impr. rangeland (ha)	1250	1250	1250	1250
Pasture land (ha)	1250	1250	1250	1250
-Deferred *Brachiaria*	87.3		109.8	
-Mixed pasture	722.3	726.7	669.1	717.3
-Yield of colonial grass (ON)		82.4	130.0	175.4
-Leucaena	125.0	125.0	125.0	125.0
-*Brachiaria* hay cut twice	50.0	50.0	50.0	50.0
-Stylo hay cut twice	265.4	265.9	166.0	182.0
Crop land (ha)	272.3	275.6	430.0	430.0
-Rice pasture assoc.	50.0	50.0		
-Sugarcane 1	74.1	69.2		
-Sugarcane 2	74.1	69.2		
-Sugarcane 3	74.1	69.2		
-Bean 2 crops			20.0	20.0
-Soybean			250.0	250.0
-Wheat				5.3
-Cassava			160.0	154.7
Feed				
-Total hay (t)	1106.9	1108.5	767.6	823.2
-Total urea (kg)	27108	25986	15752	15980
-Total molasses (kg)		5444		
-Cassava roots (t)			1187.2	1147.6

Table 16. Herd structure and animals sold in systems with and without crops under a calving rate of 90% and selling the steers at different ages.

Description	Without crops Selling ages (months) 8	 20	With crops Selling ages (months) 8	 20
Net return ($)	11109	24415	52823	66296
AU	4798.1	4327.9	4823.9	4425.3
Total cows:	3224.4	2549.7	3241.9	2607.0
Lactating pregnant	2579.6	2039.7	2593.5	2085.6
Lactating open	322.4	255.0	324.2	260.7
Dry open	322.4	255.0	324.2	260.7
Bulls	161.2	127.5	162.1	130.3
Calves	2786.0	2202.9	2801.0	2252.5
Heifers:				
8-20 months	1351.0	1068.3	1358.3	1092.3
Steers:				
8-20 months		1068.3		1092.3
Total number	7522.6	7016.7	7563.3	7174.4
Animals sold:				
Heifers 20 months old	641.7	507.4	645.1	518.8
Culled bulls	37.1	29.3	37.3	30.0
Culled cows	644.9	509.9	648.4	521.4
Steers 8 months old	1393.0		1400.5	
Steers 20 months old		1068.3		1092.3
Total No. sold	2716.7	2114.9	2731.3	2162.5
AU sold	1360.4	1334.4	1367.7	1364.5

parametric procedure was performed only on information related to systems in which the steers were sold at 8 and 32 months of age. The tendencies of net return and AU to increase or decrease with varying proportions of cultivated pastures and rangelands are shown in Fig. 6; the calving rate was assumed to be 60%. The behavior of the system under a calving rate of 50% is very similar and the discussion applies to both calving rates.

Net returns were always higher when steers were sold at 32 months of age; when less land was allocated to cultivated pastures, the differences were smaller. Net returns in general tended to increase as the proportion of land in cultivated pastures decreased; even so, the maximum optimal return was never reached. With the low calf crop that is obtained under calving rates of 60%, not more than 8% of the area should be planted to cultivated pastures when the steers are to be sold at weaning time, and no more than 10% should be allocated when the steers are sold at 32 months of age. When cultivated pasture and range are maintained at these percentages, the profit margin is about zero. When the calving rate is 50%, the percentage of area in cultivated pastures required for a break-even operation should be approximately 2% lower than under the 60% calving rate. However, in order to obtain higher net returns even less land should be allocated to cultivated pastures. The cost advantage of native range over cultivated pasture and the consequently higher profit associated with range grazing were also recorded in the findings reported by Phillips (1979) in his generation of optimal production systems for conditions such as those characteristic of Florida, and by Torres et al. (1977), who examined the

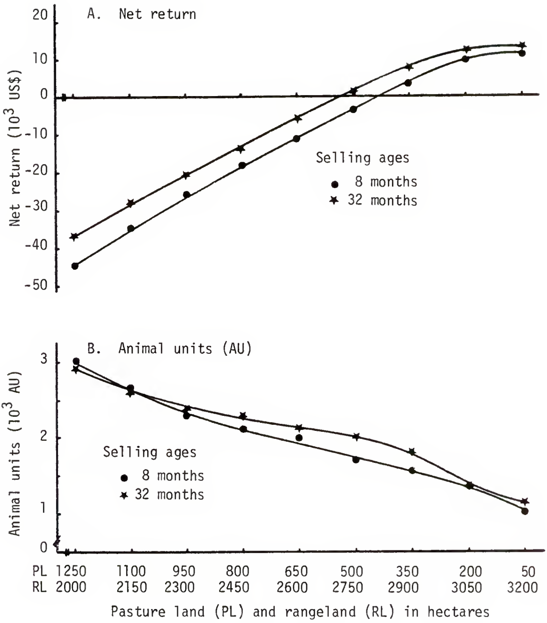

Fig. 6. Net return and animal units, decreasing pasture land (PL) and increasing proportionally rangeland (RL), at two selling ages of steers and 60% calving rate.

situation in the cerrado and found that when more than 5% of the total farm area is put into cultivated pastures, the margin of return is decreased.

As can be seen in Fig. 6, the number of AU decreased with decreasing land area in pasture; this is as expected because less forage is available. The optimal organization of any enterprise is different in each case, and the number of AU that can be supported depends on the activities selected and their productivity in the optimal solutions.

Figure 7 shows the results obtained when the calving rate was 80%; they are very similar to those rendered when the calving rate was 70%. To have a zero profit in the system selling weaned steers, approximately 15% of the area should be in cultivated pastures. When the steers were sold at 32 months of age, a positive return was generated even with 25% of the area in cultivated pastures. However, the maximum net return was obtained in the first case with 4% pasture land and in the second with 7%.

With respect to the AU in each case, they fell as the proportion of cultivated pastures decreased. The decrease in AU was almost linear for the 8-month selling age. With sales at the age of 32 months, AU increased for the first two diminutions of cultivated-pasture area and then they decreased, the values being almost the same as values obtained for the 8-month selling age when 350 ha or less were allocated to cultivated pastures. This increase in AU occurs as a result of the substitution of less productive pastures with more productive ones, such as the replacement of deferred Brachiaria or yield of colonial grass without N by mixed pastures. There was also an expressed increase both in the

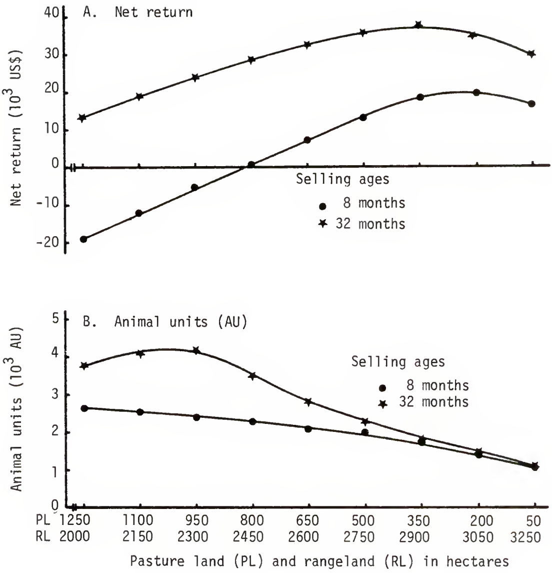

Fig. 7. Net return and animal units, decreasing pasture land (PL) and increasing proportionally rangeland (RL), at two selling ages of steers and 80% calving rate.

area cultivated with sugarcane and in the amounts of molasses and urea that had to be used to meet the nutritional requirements of the herd. Phillips (1979) found that for larger herds, higher levels of fertilization were required in order to increase forage production.

Another important aspect not analyzed in this study is the amount of capital that would have to be involved to obtain the maximum net return. The AU supported by 350 ha of cultivated pastures is around 700 AU higher than under 50 ha of cultivated pastures (Fig. 7). Capital is involved in establishing the pasture and in acquiring and/or maintaining a larger herd. Different results could be obtained by imposing restrictions on this resource; however, Oliveira et al. (1975) concluded from their study that capital was not a limiting factor in regard to increasing production in the cerrado.

Figure 8 shows the results obtained with the calving rate at 90%. In these systems net returns were always positive for the 8- and 20-month selling ages. The maximum net return was obtained with 7 and 10% of the area in cultivated pastures for the 8- and 20-month selling ages. Animal units in these two systems are numerically very close and clearly show the financial advantage of choosing the right system; it is possible that an equal number of AU can produce higher returns with the same capital investment.

The optimal enterprise organization for the solutions which gave the highest net returns for two selling ages are presented in Table 17. It was shown that the AU increased as more intensive systems were used; consequently, more productive activities and supplemental feed were required. The observation concurs with the findings of Phillips (1979).

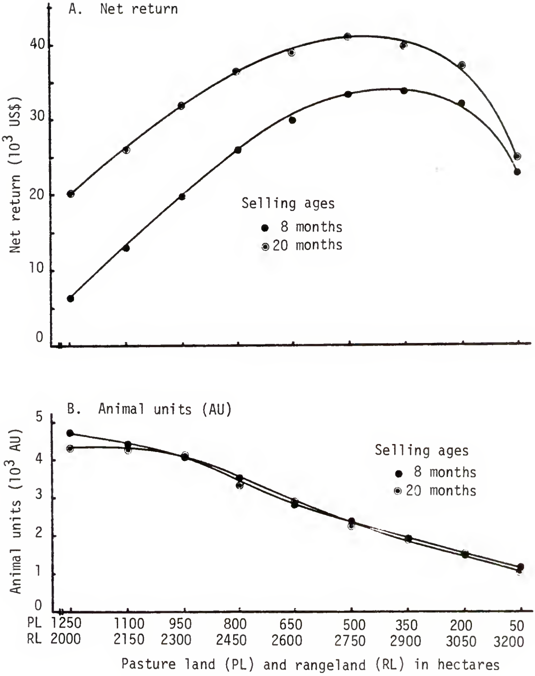

Fig. 8. Net return and animal units, decreasing pasture land (PL) and increasing proportionally rangeland (RL), at two selling ages of steers and 90% calving rate.

Net returns were increased in two ways: by keeping the steers for later sale and by improving calving rates (table 17). This clearly shows that better results can be obtained when a more complete system is practiced (Kornelius et al., 1979). Martin et al. (1978), examining the western region of São Paulo State, found the following sequence of enterprises to have increasingly advantageous net returns per ha: (1) calf-crop enterprises, (2) calf-crop plus calf-growing enterprises, (3) calf-crop plus calf-growing plus finishing enterprises, and (4) finishing operation enterprises; the last generated the highest net return. Timm (1972) also obtained better results when steers were sold at 2 1/2 years instead of 1 1/2, when the dairy cows were producing only four liters of milk. McCarthy et al. (1970) in Australia found the least profitable system to be breeding beef cattle and marketing yearlings in conjunction with the maintenance of a breeding herd.

The benefits obtained by increasing the calving rate from 60 to 80% were much greater than those associated with keeping the steers for later sale (Table 17). Monteiro et al. (1981) found that equivalent results in physical and economic terms could be obtained by either reducing the age at first calving by one year or by increasing the calving rate by 10%. In the cerrado, calving rates can be substantially increased by management practices (CPAC, 1980); cultivated pastures play an important role in this aspect. The low reproductive capacity of cows in the cerrado is the main factor limiting the incorporation of a larger number of calves into more intensive systems; normally, cow-calf enterprises are not extended credit by banking facilities for the purpose of improving their productivity (Mueller, 1977).

Table 17. Computer-determined alternatives when net returns were maximized using the parametric procedure, for two selling ages of steers and different calving rates.

Description	Calving rates (%) 60		80		90	
	8*	32*	8*	32*	8*	20*
Net returns ($)	11421	13312	18426	37160	33392	40737
AU	1038	1113	1714	1726	1869	2293
Rangeland (ha)	3200	3200	2900	2900	2900	2750
Improved rangeland (ha)	1250	1250	1250	1250	1250	1250
Pasture land (ha)	50	50	350	350	350	500
-Deferred *Brachiaria*	50	23.3	180.0	157.3	166.1	98.3
-Mixed pasture			3.5	39.9	8.9	226.7
-Leucaena		26.7	116.7	102.8	125.0	125.0
-*Brachiaria* hay cut twice			49.7	50.0	50.0	50.0
Crop land (ha)	58.7	62.3	60.8	64.4	83.6	119.9
-Rice/pasture assoc.	50.0	50.0	50.0	50.0	50.0	50.0
-Sugarcane 1	2.9	4.1	3.6	4.8	11.2	23.3
-Sugarcane 2	2.9	4.1	3.6	4.8	11.2	23.3
-Sugarcane 3	2.9	4.1	3.6	4.8	11.2	23.3
Feed						
-Total hay (t)			199.9	201.0	201.0	201.0
-Total urea (kg)				661	3007	7146
-Total molasses (kg)	27580	29176			8762	70509

*Selling ages of steers (months).

Activities selected for inclusion in the optimal solutions (Table 17) varied according to the systems. More intensive systems required more productive activites and more supplements in order to meet nutritional requirements of the herd. In the systems with a calving rate of 60% and only 50 ha of deferred *Brachiaria* pasture, molasses was required to fulfill energy requirements; this agrees with the findings of Phillips (1979) that the levels of required energy supplements increase when more range is introduced into a forage production system. Norman (1963), studying protein and energy supplementation on range pastures, concluded that conserved energy feed would be required to maintain the liveweight of the animals, because the native pasture is of little value from the first rain until rapid pasture growth begins. This situation is similar to the *cerrado*. He advised the use of legumes as a source of protein and suggested that they would be more effectively utilized in a complementary grazing system with native pasture. In this study, when the pasture area was fixed at 1250 ha, only one of the systems analyzed required molasses as a source of energy.

Sensitivity and Stability Analysis

Several activities from the optimal solutions listed in Table 17 are very sensitive. Only a slight increase in the cost of producing a hectare of the particular activities would cause them to no longer be a part of the optimal solutions. The activities that were particularly sensitive are shown below:

Activity	% increase in cost
Deferred Brachiaria	from 0.9 to 26.0
Mixed pastures	from 0.9 to 3.1
Leucaena	from 2.3 to 14.4
Brachiaria hay (cut twice)	from 5.2 to 68.0
Sugarcane	from 3.3 to 27.9

On the other hand, several activities that did not appear in the optimal solutions were also quite sensitive. Only a slight decrease in the cost of a unit of the particular activities would cause them to enter the optimal solutions. Those activities that were particularly sensitive are shown below:

Activity	% decrease in cost
Fertilized Brachiaria	from 3.3 to 15.0
Mixed pastures	from 4.2 to 9.6
Leucaena	6.3
Stylo hay (cut once)	17.2
Stylo hay (cut twice)	from 1.4 to 25.4

Sensitive activities which almost entered the optimal solution are the ones which merit attention in research planning.

Beef Sold per Ha and Stocking Rate

For the results to be more meaningful, the following factors were calculated from the optimal solutions obtained by using parametric procedures: net returns per ha, stocking rate (ha/AU) and kg/ha of liveweight sold. Net returns and beef yield (liveweight sold/ha) are presented for 50, 70 and 90% calving rates in Figs. 9, 10 and 11, and stocking rate is presented in Table 18 for the five calving rates, different pasture-range proportions, and 8- and 32-month selling ages of steers. It is evident in the three figures that beef yield increases in all systems as pasture areas increase, and beef yield is higher when steers are sold at 32 months of age. The increased beef yield was a consequence of the increased stocking rate (Table 18); this in turn was possible due to improved nutrition provided by cultivated pastures (Tothill, 1972 and Ehmke, 1980). Phillips (1979) also found that increasing the stocking rate required that resources be used more intensively; the expenses associated with such practices were found to be greater as well.

Higher stocking rates and higher beef yields do not necessarily mean higher returns. Mott (1960, p. 606) stated that "every effort should be made to attain optimum utilization of the forage" by using the appropriate stocking rate. In the discussion on his paper, he called attention to the fact that economic aspects affect the optimum stocking rate. Maximum biological production does not always lead to maximum economic production (Bryant et al., 1965). This situation is clearly shown in Figs. 9, 10 and 11. If the assumptions imposed by this study are correct, then the stocking rates in each system in

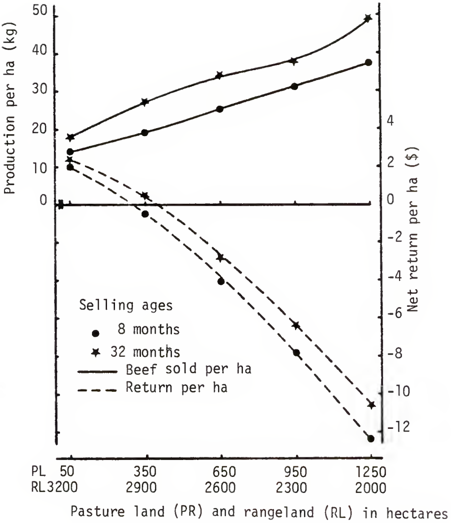

Fig. 9. Beef liveweight sold per ha per year and net return per ha, increasing pasture land (PL) and decreasing rangeland (RL), at two selling ages of steers and 50% calving rate.

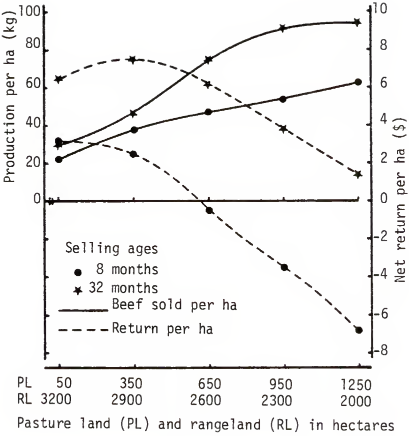

Fig. 10. Beef liveweight sold per ha per year and net return per ha, increasing pasture land (PL) and decreasing rangeland (RL), at two selling ages of steers and 70% calving rate.

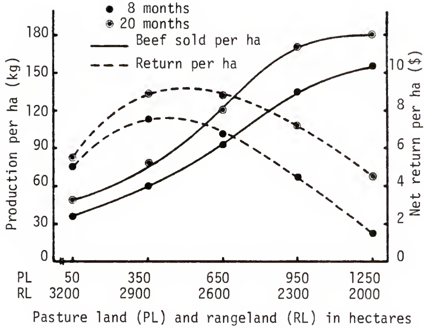

Fig. 11. Beef liveweight sold per ha per year and net return per ha, increasing pasture land (PL) and decreasing rangeland (RL), at two selling ages of steers and 90% calving rate.

Table 18 should represent the optimum. For example, at a calving rate of 70% with the sale of steers occurring at 32 months of age looking at cultivated pastures of 950 and 1250 ha, the stocking rates were almost the same, 1.48 and 1.42 ha/AU, respectively (Table 18); however, net returns were 226% higher for cultivated pasture system of 950 ha, even though beef yield was almost the same for the two sizes (Fig. 10). By considering economic aspects, more realistic results can be obtained; of course, farmers, who want to maximize net returns, are most interested in results that elucidate details associated with the generation of profits.

Beef yields varied according to the area in cultivated pastures and the system used. In the less intensive system—a calving rate of 50% and sales of weaned steers—beef yield was approximately 14 kg/ha (Fig. 9); this corroborates both the figures given by Monteiro et al. (1981) and those of Saturnino et al. (1977). By increasing the cultivated pasture area, beef yields were augmented from as much as 264% to more than 400%; even with these great increases, however, some systems were not economically feasible. The increases in beef yield, where maximum returns were obtained, varied between 27 and 69%.

Stocking rates obtained at different calving rates for the same systems of sales generally did not change very much (Table 18). What variation exists is due to the different alternatives presented in the optimal solutions and to the levels of supplemental feed utilized. For the system using only 50 ha of cultivated pasture—that is, almost pure range and improved range—the stocking rates varied between 4.44 and 5.12 ha/AU. These stocking rates seems to approach some estimates,

Table 18. Net returns (NR) per ha and stocking rate (ha/AU) affected by decreasing pasture land (PL) and increasing proportionally rangeland (RL), at different calving rates and selling ages of steers.

Calving rates (%)			Pasture land (PL) and rangeland (RL)—ha									
		PL	1250	950	650	350	50	1250	950	650	350	50
		RL	2000	2300	2600	2900	3200	2000	2300	2600	2900	3200
			---------8 month selling age--------					------32 month selling age*--------				
50	NR/ha		-10.98	-6.98	-3.63	-0.40	1.69	-9.39	-5.67	-2.56	0.36	2.08
	ha/AU**		1.83	2.20	2.67	3.52	4.85	1.70	2.18	2.48	3.12	4.64
60	NR/ha		-8.87	-5.27	-2.22	0.64	2.28	-7.37	-4.13	-1.19	1.56	2.66
	ha/AU		1.66	2.17	2.53	3.24	4.82	1.71	2.10	2.37	2.77	4.49
70	NR/ha		-6.05	-3.15	-0.39	2.19	2.76	1.26	3.39	5.44	6.72	5.80
	ha/AU		1.80	2.06	2.36	2.90	5.12	1.42	1.48	1.79	2.83	4.52
80	NR/ha		-3.77	-1.15	1.40	3.69	3.26	2.68	4.75	6.50	7.43	5.94
	ha/AU		1.85	2.08	2.39	2.92	4.69	1.33	1.21	1.79	2.90	4.73
90	NR/ha		1.30	3.92	5.95	6.68	4.52	4.04	6.36	7.78	7.92	4.90
	ha/AU		1.06	1.20	1.75	2.68	4.44	1.15	1.21	1.71	2.66	4.79

* The selling age at 90% calving rate is 20 months.

** Obtained by dividing total farm area by the AU. In reality some area was not used and the stocking rate should be somewhat higher.

although in this study the nutrient requirements of the cattle were met. Centro Internacional de Agricultura Tropical (1978) reported stocking rates of 3.2 to 3.6 ha/animal; these values would increase if, instead of using the number of animals in their calculations of stocking rate, they had used AU. The experience at the Cerrado Research Center is that 3 ha/cow is too high a stocking rate under that cerrado range condition.

Rational Utilization of the Cerrado

An overall analysis of the model used in this study indicates that it is far from being complete; on the other hand, the results obtained seem to be close to reality. Coefficients must be checked, cost and prices actualized, and more alternatives and resources included. If belief and enthusiasm regarding the potential of the cerrado region for food production had existed before working with this model, they were encouraged by the possibility and feasibility of adjusting biological and economic production through the use of linear programming.

Cattle production, especially breeding activities, cannot compete with either crop production (Oliveira et al., 1975) or timber production (McCarthy et al., 1970), but the potential for intensive fattening, according to Preston (1975, p. 149), "promises to be greater than anywhere else in the world." He stated that the feed-converting abilities of Zebu-type cattle are at least 20% inferior to those of the improved European breeds. Meanwhile, Moore and Mott (1973) did not find clear distintions between the quality of temperate and tropical grasses. They concluded that daily gain by beef cattle grazing tropical and subtropical grasses may routinely equal 600 g/day and can, in some cases be appreciably higher.

Paladines (1975) believes that in order to obtain significant progress in tropical savannas, it will be necessary to change the native grass species to others of higher productivity and feeding value that are equally persistent in the environment. In the model studied, significant increases were obtained in beef yield; in some cases, important gains were made on farms with very little area in cultivated pastures. In livestock production it is important to maintain an equilibrium between feed supply and the animals' nutritional requirements. Several alternatives for accomplishing this were suggested by Mott (1960), and some were used in the model. Preston (1975) suggested that the stocking rate should be adjusted for the rainy season with supplements added to the diets during the dry season in order to accomplish the same stocking rate year around. Van Niekerk (1975) is in favor of strategic supplementation, because it minimizes supplementary feeding costs and allows more efficient and complete use of natural pastures, while significantly increasing productivity. The fulfillment of nutrient requirements on the monthly bases established in this model had this as an objective and the model clearly showed when some supplement was required.

The ideal farming system, if one exists, should try to integrate several phases of the farming production process, making the best use of resources in order to obtain maximum economic production. Linear programming is an aid that enhances the "systems" approach. Woolcock (1972) pointed out that improved pastures, fodder crops and crop residues are extremely important aspects to consider in efforts aimed at increasing the reproductive performance of breeding herds; he also emphasized the notion that production can be increased without using costly inputs. Little information is available on such systems in the cerrado, even though it is generally agreed that low inputs in beef production should be an objective of any good program for tropical areas.

Rickert and Winter (1980) in their review concluded that the integration of various pasture or forage options needs more study. If feed production is improved, it becomes imperative to improve management practices and breeding as well. The systems grow in complexity. Then, the following question becomes appropriate: what sound reasons exist for including crops, annual or perennial, in the systems? The results obtained in this study showed the advantage in net returns when crops were coupled with livestock production. Prevatt (1979) pointed out several reasons which justify this procedure, including better use of land resources, better distribution of labor throughout the year, and more efficient use of machinery and complements. Grawunder and Mielitz Neto (1979) found that labor was better distributed throughout the year when supplementation was used in the system. All these aspects apply to the cerrado region. It can be added that it is important to retain laborers on the farm, diminishing the exodus to the cities. A more complete system seems to be generally more appropriate for agricultural exploitation of the cerrado. Identifying weaknesses in the system and indicating guidelines for future research are possibly the fundamental virtues pertaining to the use of linear programming.

Barcellos and Kornelius (1977) suggested that beef production systems that need to be studied in the cerrado should be directed toward: (1) rational and efficient use of the natural resources, (2) reduction of the mortality rate, (3) increase in the reproductive efficiency of cattle, and (4) curtailment of the raising period. For fattening systems it can be added that it is necessary to increase daily gain during the fattening period in order to decrease the slaughter age. This study showed that with small changes, a drastic impact in productivity can be anticipated, bringing socioeconomic benefits to the region. This study is a contribution to the search for rational systems for the cerrado region.

CHAPTER IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The cerrado region of Brazil comprises more than 180 million ha, about 20% of the total land area of the country. The main exploitation is an extensive cow-calf operation system of low productivity. Approximately 36% of the Brazilian cattle herd is located in the cerrado. Besides beef production, rice, corn and beans are important crops cultivated in the region.

The objectives of this study pertained to identification of alternatives agricultural systems for the region, systems that would be more productive in biological and economic terms. A corollary purpose was to become acquainted with linear programming as a tool for studying complex agricultural systems. The optimal organization of farm enterprises, the identification of weaknesses in existing systems and determination of priority areas for future study are the consequences of applying systems analysis to the conditions presented by the cerrado area.

The beef industry is based on the utilization of different cerrado rangelands. As a frontier region, low land prices favor calf production, with 65% of the enterprises engaging in this type of operation. Approximately 30% of the enterprises include raising calves in addition to cow-calf operations. Well-defined wet and dry seasons bring shortages of feed supply from May to October; this is the dry season, with the most critical months being June, July, August and September. In order to assure productivity, some kind of supplementation is required during this period; this study was developed upon the hypothesis that the herds' nutrient requirements could be met with forage supplementation systems. Alternatives programmed into the system included five calving rates—50, 60, 70, 80 and 90%—and four selling ages of steers—at 8, 20, 32 and 44 months. Forage alternatives included range, improved range, cultivated forage species, levels of N fertilization, mixed pastures, hay-making, deferred pastures and irrigated pastures. Supplementation alternatives included purchase of concentrated feed-namely, molasses, urea, cottonseed meal and soybean meal; production on the farm of sugarcane, hay, corn, cassava leaves and roots, irrigated pasture, crop residues were considered as additional sources of feed supplements.

Cash crop alternatives that are feasible for the region included those commonly cultivated—rice, corn and beans—as well as some crops potentially profitable for the cerrado—soybean, wheat and cassava.

A fixed area of 5000 ha was used; the land was divided into four categories according to the following plan: (1) 40% in rangeland, (2) 25% in improved rangeland, (3) 25% in cultivated pasture land, and (4) 10% in crop land.

With 25% of the total area in improved pastures, the optimal organizations presented negative net returns at all selling ages of steers under calving rates of 50 and 60%. Under calving rates of 70 and 80%, net returns were positive only when steers were sold at 32 months of age.

When the calving rate was 90%, net returns were positive when steers were sold at 8 and 20 months of age.

Under all calving rates, net returns were increased by increasing the selling ages of steers.

When crops were added to the systems, the increase in net returns was almost constant due to the restriction in cropping area. All systems with calving rates at 70% or higher had positive net returns, as did systems operating under the calving rate of 50% when steers were sold at 44 months and under the rate of 60% when steers were sold at 32 or 44 months of age.

Soybeans, beans, wheat and cassava were the crops that appeared in all optimal solutions.

The AU in each system varied as a result of variation in herd structure and the selection of alternatives to provide higher returns. Within each calving rate, AU decreased when steers were sold at 20 months and increased when the age at time of sale was 32 or 44 months.

The greatest increase in the number of animals supported within each calving rate occurred at 70 and 80% with steers being sold at 32 months of age. Under the 90% calving rate, the number of animals decreased when steers were sold at the age of 20 months.

Excluding the 90% calving rate, the number of AU sold within each calving rate increased as the age at which the animals were sold was raised; AU increased for the same selling age under various calving rates.

The number of animals sold within each calving rate decreased as the selling ages were raised and increased as calving rates for the same selling age were elevated.

The addition of crops to the systems affected neither the total AU produced nor the number of animals obtained in each system.

Net returns increased under calving rates of 50 and 60% when the area in pasture decreased while rangeland increased by a comparable amount. Maximum net return was obtained when only 50 ha were in cultivated pastures. To achieve approximately zero net return, no more than 6 or 8% of the area should be in cultivated pastures when calving rates are 50 and 60% respectively.

For calving rates of 70, 80 and 90% maximum net returns were reached when varying amounts of land area were devoted to cultivated pasture; the returns were always higher, however, when steers were sold at the age of 32 months rather than at 8 months. Net returns were maximized by selling steers at weaning time when the area in cultivated pasture was 4% and calving rates were 70 and 80%, likewise when the area in cultivated pasture approached 7% and the calving rate was 90%. When steers were sold at 32 months of age, an additional 3% of cultivated pastures were required to obtain maximum net returns.

Liveweight sold per ha (beef yield) always increased as the area in cultivated forage was augmented. However, net returns per ha did not follow this pattern. An inverse relationship existed between beef yield and net returns for the two selling ages analyzed when the area in cultivated pastures was increased from 1 to 25% and calving rates were 50 and 60%. Maximum net return per ha was obtained by systems with the lowest cultivated pasture area (50 ha); they sold from 14 to 21 kg of liveweight per ha. Under calving rates of 70, 80 and 90% beef yield varied between 22 and 179 kg/ha. The beef yield generating the maximum net returns when sales occurred at 8 and 32 months were, respectively, 28 and 47 kg/ha under 70% calving rate, 36 and 48 kg/ha under 80% calving rate, and under a calving rate of 90% beef yields were 61 and 95 kg/ha for the 8- and 20-month selling ages, respectively.

Stocking rates changed by approximately 10% for the four lower calving rates when the area in pasture was held constant and the steers were sold at weaning time. When steers were sold at the age of 32 months, the stocking rates were similar for the 50 and 60% calving rates considered one group and 70, 80 and 90% taken as another. Stocking rates increased as the land in pasture increased. With only 1% of the total area in cultivated pasture, the stocking rate was approximately 4.5 ha/AU; with 25% in cultivated pasture, the stocking rate varied between 1.06 and 1.85 ha/AU.

When 25% of the area was in cultivated pasture, the activities which consistently appeared in the optimal solutions were deferred pastures, yield of colonial grass without N, rice/pasture association, hay making and sugarcane. When crops were added to the scheme, cassava (aerial parts and roots) replaced both sugarcane and rice/pasture association. Mixed pasture also appeared in the optimal solution as AU increased sharply under the calving rate of 90%.

Of the purchased sources of supplements, only urea was included in every single optimal solution. Although energy was the most limiting nutrient, urea supplements were mainly required in July and August, otherwise existing forage and crops fulfilled the herd's nutritional requirements. Sugarcane and cassava were the main sources of energy.

The area devoted to their cultivation increased as calving rates increased while selling age was held constant.

In the systems returning maximum profits with varying amounts of land in pasture, more productive and costly forage alternatives were required as calving rates and/or selling ages increased. In terms of purchased supplements, molasses was required in various optimal solutions generating maximum profits; usually it was needed in February and October when sugarcane was not available. Urea was also required mainly under 90% calving rate for the months of July, August and September.

Conclusions

In conjunction with the stipulated assumptions, the following conclusions can be drawn from this study;

Stocking rate and liveweight sold per ha can be increased by increasing the area in cultivated pastures.

Maximum biological production (liveweight sold per ha) does not imply maximum economic returns.

Net returns per ha can be increased either by increasing the calf crop or by incorporating a finishing phase into the system. At lower calving rates, better results were obtained by increasing calving rate than by keeping steers for later sale.

Net returns from beef enterprises were dependent on the system of production. In cow-calf operations where calving rates are either 50 or 70%, not more than 1 or 4% of total land area should be cultivated pasture. Precise recommendations of the appropriate area to be planted in cultivated pasture must depend upon several factors and should only be made if the particular system and the specific conditions which apply are known.

Raising and fattening steers generated greater net returns than did sale of steers at weaning. In situations where cultivated pastures are already present, raising and fattening should be incorporated into the systems.

The improvement of calving rates should be pursued, especially when they are very low. Increased rates will generate better economic returns and will provide more units for other phases of beef production.

Establishing the monthly nutrient requirements of the herd allows for adjustments to be made according to the forage production, and permits identification of times when supplements will be required, lowering the supplementation costs.

Supplementation either in the dry season or in periods of production shortage permits better utilization of the potential DM production of the cerrado during the rainy season.

More complete beef systems, including cash crops, can encourage the stability of farm enterprises and permit better utilization and distribution of resources throughout the year.

Recommendations

The optimal plans obtained from this study are not directly applicable to any single farming situation in the cerrado area. Adjustments must be made to accomodate the circumstances imposed by a particular farm situation, if meaningful results are to be obtained.

It is important to emphasize the deep need for information about the cerrado beef yield and calf crop in the different range environments. Little research data are available on DM production on a monthly basis, on the quality of DM production, or its intake by cattle.

The stocking rate should be determined for range conditions taking into consideration both dry and wet seasons, and the effect on stocking rate when cultivated pastures are used should be considered.

The effects of using cultivated pasture in conjunction with rangeland as manifested by calving rates and total system output should also be investigated.

The different advantages pertaining to the use of sugarcane, cassava or leucaena as sources of energy and protein during the dry period should be better determined in field trials that simulate real systems.

More information should also be obtained regarding the production and duration of a cultivated pasture under grazing condition in the cerrado; in addition, the costs of maintaining good productivity should also be studied.

The legume effect on forage DM production and quality in mixtures, especially during the dry season, should be determined. The introduction of legumes under range condition is also very important. Procedures for introduction and management, as well as analyzing the potential contribution of legumes to the system are matters that require precise attention.

Both hay and deferred pastures seem to be important supplementation alternatives for the cerrado region; thus the economic feasibility and agronomic viability merit more research.

Calf crops continue to be important economic activities in the cerrado; consequently, special attention should be directed toward increasing calving rates. Credit facilities and alternative options for forage production and utilization should be provided to farmers in order to enhance the attractiveness of cow-calf operations.

Finally, the determination of the nutrient requirements for Zebu-type cattle should be studied and compared with the NRC tables which are calculated for European cattle.

APPENDIX

Table 19. Code abbreviation, description, constraint and unit of measurement for row elements.

Code	Description	Constraint*	RHS	Unit
OBJMAX	Objective function (Net returns)	N		dollar
DM_i	Dry matter balanced per month	L	0	kg
ME_i	Metabolizable energy balanced per month	G	0	Mcal
DP_i	Digestible protein balanced per month	G	0	kg
TR_i	Range forage transfer from one month to the next	L	0	kg
TIR_i	Improved range forage transfer from one month to the next	L	0	kg
$TRSUGA_i$	Sugarcane transfer to give the effect of a 3-year rotation	E	0	ha
HAYUSE	Grass hay transfer used to insure that all hay produced is consumed	E	0	kg
LHAYUSE	Legume hay transfer used to insure that all hay produced is consumed	E	0	kg
HAYMAKE	Total hay produced row	G	0	ton
HLAND	Land available to make grass hay	L	50	ha
RLAND	Land available for range	E	2000	ha
IRLAND	Land available for improved range	E	1250	ha
PLAND	Land available for cultivated pastures	E	1250	ha
CLAND	Land available for crops	E	430	ha
RICEPA	Land available for rice/pasture association	L	50	ha
IRRLAND	Land available for irrigated ryegrass	L	20	ha
TRRGSEED	Ryegrass seed transfer row for sale	E	0	kg
CASROOTS	Cassava roots transfer row for feed or for sale	E	0	ton
TRCORN	Corn grain transfer row for feed or for sale	E	0	ton

Table 19. Continued

Code	Description	Constraint*	RHS	Unit
CSTUBBLE	Corn stubble transfer row for grazing either in July or July and August	E	0	ton
TSTRAW	Rice straw transfer row for three different periods of use	E	0	ton
LEUCALLO	Hectares allotted to leucaena	L	125	ha
BEALLO	Hectares allotted to beans	L	20	ha
SOYALLO	Hectares allotted to soybeans	L	250	ha
AU	Total animal units	N		AU**
LAPRECOW	Lactating pregnant cow transfer row	E	0	AU
LAOPCOW	Lactating open cow transfer row	E	0	AU
DRYPRCOW	Dry pregnant cow transfer row	E	0	AU
BULLS	Bull transfer row	E	0	AU
CALVES	Calf transfer row	E	0	AU
HF2	Heifers approaching two years transfer row	E	0	AU
HF3	Heifers approaching three years transfer row	E	0	AU
HF4	Heifers approaching four years transfer row	E	0	AU
ST2	Steers approaching two years transfer row	E	0	AU
ST3	Steers approaching three years transfer row	E	0	AU
ST4	Steers approaching four years transfer row	E	0	AU
SST2	Stocked steers approaching two years transfer row	E	0	AU
SST3	Stocked steers approaching three years transfer row	E	0	AU
SST4	Stocked steers approaching four years transfer row	E	0	AU
WEST	Weaned steers transfer row	E	0	AU
HEIF	Heifer transfer row	E	0	AU

Table 19. Continued

Code	Description	Constraint*	RHS	Unit
CUBULLS	Culled bull transfer row	E	0	AU
CUCOWS	Culled cow transfer row	E	0	AU

* E = equality, L = less than or equal to, G = greater than or equal to and N = no constraint

** signifies animal unit; a single AU is defined as one dry open cow.

Table 20. Code abbreviation, description and unit measurement for column activities used in the model.

Code	Description	Unit
RANGE	Range forage production activity	ha
IRANGE	Improved range forage production activity	ha
CO_iR	Range carry-over activity from January through December	kg
CO_iIR	Improved range carry-over activity from January through December	kg
LEUCAENA	Leucaena pasture production activity	ha
RYEGRASS	Ryegrass pasture production activity under irrigation	ha
RYESESA	Ryegrass seed sale activity	kg
FBRA	Fertilized *Brachiaria* production activity	ha
DEFEBRA	Deferred *Brachiaria* production activity	ha
MIXPAST	Mixed pasture production activity	ha
COYLD1	Yield of colonial grass activity at zero N level	ha
COYLD2	Yield of colonial grass activity with 100 kg of N/ha	ha
COYLD3	Yield of colonial grass activity with 200 kg of N/ha	ha
GRSTYLO	*Stylosanthes* grazing production activity	ha
HAYSTY1	*Stylosanthes* activity, cutting hay once and grazed in the dry season	ha
HAYSTY2	*Stylosanthes* activity, cutting hay twice and grazed in the dry season	ha
MHAY	Making hay activity, cutting *Brachiaria* for hay twice and grazing it in the dry season	ha
RIPAST	*Brachiaria* associated with rice production activity in the first year used in the dry season	ha
SUCANE	First year sugarcane production activity	ha
SYCANE2	Second year sugarcane production activity	ha
SUCANE3	Third year sugarcane production activity	ha
HAY_i	Grass hay activities available from January through December	kg

Table 20. Continued

Code	Description	Unit
$LHAY_i$	Legume hay activities available from January through December	kg
$UREA_i$	Urea activities available from January through December	kg
$COTM_i$	Cotton meal activities available from January through December	kg
$SOBM_i$	Soybean meal activities available from January through December	kg
$MOLA_i$	Molasses activities available from January through December	kg
CASAP	Cassava aerial parts production activity	ha
CASRO	Cassava root production activity to feed cattle	ton
SACARO	Sale of cassava roots activity	ton
RICE	Rice crop activity	ha
MRISTRAW	Rice straw activity fed in May, June and July	ton
RISTRAW	Rice straw activity fed in June, July and August	ton
JRISTRAW	Rice straw activity fed in July, August and September	ton
CORNAEP	Corn dry plant activity, chopped and fed in June, July, August and September	ha
GRCORN	Corn grazing activity, total plant grazed in June, July, August and September	ha
COGRAIN	Corn grain production activity	ha
FEDCORN	Corn grain fed activity, for July, Aug., Sept. and Oct.	ton
CORNSA	Corn grain sale activity	ton
COSTU	Corn stubble activity to be grazed in July	ton
COSTU2	Corn stubble activity to be grazed in July and August	ton
BEANONE	Beans activity, cropped once per year	ha
BE2CRO	Beans activity, cropped twice per year	ha
SOYBEAN	Soybean activity	ha
WHEAT	Wheat crop activity	ha

Table 20. Continued

Code	Description	Unit
AUREQ	Animal unit requirements activity	AU*
LPCOW	Lactating pregnant cow, additional requirement activity	AU
LOCOW	Lactating open cow, additional requirement activity	AU
DPCOW	Dry open cow, additional requirement activity	AU
BURQ	Bulls additional requirement activity	AU
CARQ	Calf requirement activity	AU
HF2RQ**	Heifers from 8 to 20 months, additional req. activity	AU
HF3RQ**	Heifers from 20 to 32 months, additional req. activity	AU
ST2RQ**	Steers from 8 to 20 months, additional req. activity	AU
ST3RQ**	Steers from 20 to 32 months, additional req. activity	AU
ST4RQ**	Steers from 32 to 44 months, additional req. activity	AU
WESTSA***	Weaned steers sale activity	AU
HFSALE***	Heifer sale activity	AU
CUBUSA	Culled bulls sale activity	AU
CUCOSA	Culled cows sale activity	AU

* Signifies animal unit; a single AU is defined as one dry open cow.

** Requirements vary, according to assumptions in Table 6.

*** Sale of steers can occur at 8, 20, 32 and 44 months and sale of heifers at 20, 32 and 44 months of age.

Table 21. The linear programming matrix for maximizing net returns obtained using the control procedure TRANCOL.

	RANGE	CDJAR	CDFEB	CDMAR	CDAPR	CDMYR	CDJNR	CDJLR
OBJMAX	1.79000-							
DMJA	83.00000	1.00000-						
MEJA	145.00000	1.75000-						
DPJA	5.20000	.06300-						
DMFE	88.00000	.70000	1.00000-					
MEFE	154.00000	1.22500	1.75000-					
DPFE	5.50000	.04400	.06300-					
DMMA	80.00000		.70000	1.00000-				
MEMA	140.00000		1.22500	1.75000-				
DPMA	5.00000		.04400	.06300-				
DMAP	52.00000			.70000	1.00000-			
MEAP	87.00000			1.22500	1.68000-			
DPAP	1.00000			.04400	.02000-			
DMMY	34.00000				.40000	1.00000-		
MEMY	57.00000				.67000	1.68000-		
DPMY	.70000				.00800	.02000-		
DMJN	17.00000					.40000	1.00000-	
MEJN	28.00000					.67000	1.68000-	
DPJN	.30000					.00800	.02000-	
DMJU	15.00000						.40000	1.00000-
MEJU	25.00000						.67000	1.68000-
DPJU	.30000						.00800	.02000-
DMAG	15.00000							.40000
MEAG	25.00000							.67000
DPAG	.30000							.00800
DMSE	19.00000							
MESE	32.00000							
DPSE	.40000							
DMOC	45.00000							
MEOC	79.00000							
DPOC	2.80000							
DMNO	61.00000							
MENO	107.00000							
DPNO	3.60000							
DMDE	74.00000							
MEDE	130.00000							
DPDE	4.70000							
TRJF	83.00000-	1.00000						
TRFM	88.00000-		1.00000					
TRMA	80.00000-			1.00000				
TRAM	52.00000-				1.00000			
TRMJ	34.00000-					1.00000		
TRJJ	17.00000-						1.00000	
TRJA	15.00000-							1.00000
TRAS	15.00000-							
TRSO	19.00000-							
TRON	45.00000-							
TRND	61.00000-							
TRDJ	74.00000-							
RLAND	1.00000							

Table 21. Continued

	COAGR	COSER	COOCR	CONOR	CODER	IRANGE	COJAIR	COFEIR
OBJMAX						3 45000-		
DMJA						108 00000	1.00000-	
MEJA						191 00000	1 77000-	
DPJA						10 30000	09500-	
DMFE						111 00000	70000	1.00000-
MEFE						186 00000	1.24600	1.66000-
DPFE						10.20000	06700	09200-
DMMA						137 00000		70000
MEMA						327.00000		1.18000
DPMA						13 70000		04400
DMAP						98.00000		
MEAP						161 00000		
DPAP						8 40000		
DMMY						110 00000		
MEMY						186 00000		
DPMY						11 00000		
DMJN						88.00000		
MEJN						143 00000		
DPJN						7.20000		
DMJU						71 00000		
MEJU						140 00000		
DPJU						6.90000		
DMAG	1.00000-					81.00000		
MEAG	1.68000-					116.00000		
DPAG	02000-					8.90000		
DMSE	40000	1 00000-				77.00000		
MESE	67000	1.68000-				116 00000		
DPSE	00800	02000-				7 20000		
DMOC		70000	1.00000-			92 00000		
MEOC		1.22500	1.75000-			154.00000		
DPOC		04400	.06300-			11.50000		
DMNO			.70000	1.00000-		85.00000		
MENO			1.22500	1.75000-		171 00000		
DPNO			.04400	06300-		9 30000		
DMDE				.70000	1.00000-	128 00000		
M[illegible]				1 22500	1.75000-	200 00000		
D[illegible]				04400	06300-	12.40000		
TRAS	1.00000							
TRSO		1 00000						
TRON			1 00000					
TRND				1.00000				
TRDJ					1.00000			
TIRJF						108.00000-	1 00000	
TIRFM						111.00000-		1 00000
TIRMA						137 00000-		
TIRAM						98 00000-		
TIRMJ						110 00000-		
TIRJJ						86 00000-		
TIRJA						71.00000-		
TIRAS						81 00000-		
TIRSO						77 00000-		
TIRON						92 00000-		
TIRND						85.00000-		
TIRDJ						128 00000-		
IRLAND						1 00000		

Table 21. Continued

	COMAIR	COMPIR	COMYIR	COJNIR	COJUIR	COAGIR	COSEIR	COOCIR
DMMA	1.00000-							
MEMA	2.39000-							
DPMA	10000-							
DMAP	70000	1.00000-						
MEAP	1.67000	1.64000-						
DPAP	.67000	08600-						
DMMY		40000	1.00000-					
MEMY		66000	1.69000-					
DPMY		.03400	.10000-					
DMJN			.40000	1.00000-				
MEJN			.68000	1.62000-				
DPJN			.04000	08200-				
DMJJ				40000	1.00000-			
MEJJ				65000	1.97000-			
DPJJ				03300	09700-			
DMAG					40000	1.00000-		
MEAG					79000	1.43000-		
DPAG					03900	.11000-		
DMSE						40000	1.00000-	
MESE						1.00000	1.51000-	
DPSE						04400	09300-	
DMOC							70000	1.00000-
MEOC							1.06000	1.67000-
DPOC							06500	12500-
DMNO								70000
MENO								1.17000
DPNO								07700
TIRMA	1.00000							
TIRAM		1.00000						
TIRMJ			1.00000					
TIRJJ				1.00000				
TIRJA					1.00000			
TIRAS						1.00000		
TIRSO							1.00000	
TIFON								1.00000

	CONOIR	CODEIR	MOLAJA	MOLAFE	MOLAMA	MOLAAP	MOLAMY	MOLAJN
DPJMAX			08580-	08580-	08580-	08580-	08580-	08580-
DMJA			1.00000					
MEJA			3.29000					
DPJA			02400					
DMFE				1.00000				
MEFE				3.29000				
DPFE				02400				
DMMA					1.00000			
MEMA					3.29000			
DPMA					02400			
DMAP						1.00000		
MEAP						3.29000		
DPAP						02400		
DMMY							1.00000	
MEMY							3.29000	
DPMY							02400	
DMJN								1.00000
MEJN								3.29000
DPJN								02400
DMNO	1.00000-							
MENO	2.01000-							
DPNO	11000-							
DMDE	70000	1.00000-						
MEDE	1.41000	1.56000-						
DPDE	07730	09700-						
TIRNO	1.00000							
TIRDJ		1.00000						

Table 21. Continued

	MOLAJU	MOLAAG	MOLASE	MOLAOC	MOLANO	MOLADE	UREAJA	UREAFE
DRJMAX	06580-	.08580-	.08580-	08580-	.08580-	08580-	.13160-	.13160-
DMJA							1.00000	
DPJA							2.46400	
DMFE								1.00000
DPFE								2.46400
DMJU	1.00000							
MEJU	3.29000							
DPJU	.02400							
DMAG		1.00000						
MEAG		3.29000						
DPAG		.02400						
DMSE			1.00000					
MESE			3.29000					
DPSE			02400					
DMOC				1.00000				
MEOC				3.29000				
DPOC				02400				
DMNO					1.00000			
MENO					3.29000			
DPNO					02400			
DMDE						1.00000		
MEDE						3.29000		
DPDE						02400		

	UREAMA	UREAAP	UREAMY	UREAJN	UREAJU	UREAAG	UREASE	UREAOC
DRJMAX	13160-	.13160-	.13160-	.13160-	13160-	13160-	13160-	13160-
DMMA	1.00000							
DPMA	2.46400							
DMAP		1.00000						
DPAP		2.46400						
DMMY			1.00000					
DPMY			2.46400					
DMJN				1.00000				
DPJN				2.46400				
DMJU					1.00000			
DPJU					2.46400			
DMAG						1.00000		
DPAG						2.46400		
DMSE							1.00000	
DPSE							2.46400	
DMOC								1.00000
DPOC								2.46400

Table 21. Continued

	UREAKO	UREADE	COTNJA	COTNFE	COTNMA	COTNAP	COTNMY	COTNJN
OBJMAX	.13160-	.13160-	.12230-	.12230-	.12230-	.12230-	.12230-	.12230-
DNJA			1.00000					
MEJA			2.82000					
DPJA			.35300					
DNFE				1.00000				
MEFE				2.82000				
DPFE				.35300				
DNMA					1.00000			
MEMA					2.82000			
DPMA					.35300			
DNAP						1.00000		
MEAP						2.82000		
DPAP						.35300		
DNMY							1.00000	
MEMY							2.82000	
DPMY							.35300	
DNJN								1.00000
MEJN								2.82000
DPJN								.35300
DNKO	1.00000							
DPKO	2.46400							
DNDE		1.00000						
DPDE		2.46400						

	COTNJU	COTNAG	COTNSE	COTNOC	COTNNO	COTNDE	SOBNJA	SOBNFE
OBJMAX	.12230-	.12230-	.12230-	.12230-	.12230-	.12230-	.15110-	.15110-
DNJA							1.00000	
MEJA							2.93000	
DPJA							.43800	
DNFE								1.00000
MEFE								2.93000
DPFE								.43800
DNJU	1.00000							
MEJU	2.82000							
DPJU	.35300							
DNAG		1.00000						
MEAG		2.82000						
DPAG		.35300						
DNSE			1.00000					
MESE			2.82000					
DPSE			.35300					
DNOC				1.00000				
MEOC				2.82000				
DPOC				.35300				
DNNO					1.00000			
MENO					2.82000			
DPNO					.35300			
DNDE						1.00000		
MEDE						2.82000		
DPDE						.35300		

Table 21. Continued

	SOBMMA	SOBMAP	SOBMMY	SOBMJN	SOBMJU	SOBMAG	SOBMSE	SOBMOC
OBJMAX	.15110-	.15110-	.15110-	.15110-	.15110-	.15110-	.15110-	.15110-
DMMA	1.00000							
MEMA	2.93000							
DPMA	.43800							
DMAP		1.00000						
MEAP		2.93000						
DPAP		.43800						
DMMY			1.00000					
MEMY			2.93000					
DPMY			.43800					
DMJN				1.00000				
MEJN				2.93000				
DPJN				.43500				
DMJU					1.00000			
MEJU					2.93000			
DPJU					.43800			
DMAG						1.00000		
MEAG						2.93000		
DPAG						.43800		
DMSE							1.00000	
MESE							2.93000	
DPSE							.43800	
DMOC								1.00000
MEOC								2.93000
DPOC								.43800

	SOBMNO	SOBMDE	HAYJA	HAYFE	HAYMA	HAYAP	HAYMY	HAYJN
OBJMAX	.15110-	.15110-	.00130-	.00130-	.00130-	.00130-	.00130-	.00130-
DMJA			1.00000					
MEJA			1.97000					
DPJA			.05500					
DMFE				1.00000				
MEFE				1.97000				
DPFE				.05500				
DMMA					1.00000			
MEMA					1.97000			
DPMA					.05500			
DMAP						1.00000		
MEAP						1.97000		
DPAP						.05500		
DMMY							1.00000	
MEMY							1.97000	
DPMY							.05500	
DMJN								1.00000
MEJN								1.97000
DPJN								.05500
DMNO	1.00000							
MENO	2.93000							
DPNO	.43800							
DMDE		1.00000						
MEDE		2.93000						
DPDE		.43800						
HAYUSE			1.00000-	1.00000-	1.00000-	1.00000-	1.00000-	1.00000-

Table 21. Continued

	HAYJU	HAYAG	HAYSE	HAYOC	HAYNO	HAYDE	LHAYJA	LHAYFE
DP.JMAX	.00130-	.00130-	.00130-	.00130-	.00130-	.00130-	.00130-	.00130-
DMJA							1.00000	
MEJA							2.05000	
DPJA							.12/60	
DMFE								1.00000
MEFE								2.05000
DPFE								.12670
DMJU	1.00000							
MEJU	1.97000							
DPJU	.05500							
DMAG		1.00000						
MEAG		1.97000						
DPAG		.05500						
DMSE			1.00000					
MESE			1.97000					
DPSE			.05500					
DMOC				1.00000				
MEOC				1.97000				
DPOC				.05500				
DMNO					1.00000			
MENO					1.97000			
DPNO					.05500			
DMDE						1.00000		
MEDE						1.97000		
DPDE						.05500		
HAYUSE	1.00000-	1.00000-	1.00000-	1.00000-	1.00000-	1.00000-		
LHAYUSE							1.00000-	1.00000-

	LHAYMA	LHAYAP	LHAYMY	LHAYJN	LHAYJU	LHAYAG	LHAYSE	LHAYOC
DP.JMAX	.00130-	.00130-	.00130-	.00130-	.00130-	.00130-	.00130-	.00130-
DMMA	1.00000							
MEMA	2.05000							
DPMA	.12670							
DMAP		1.00000						
MEAP		2.05000						
DPAP		.12670						
DMMY			1.00000					
MEMY			2.05000					
DPMY			.12670					
DMJN				1.00000				
MEJN				2.05000				
DPJN				.12670				
DMJU					1.00000			
MEJU					2.05000			
DPJU					.12670			
DMAG						1.00000		
MEAG						2.05000		
DPAG						.12670		
DMSE							1.00000	
MESE							2.05000	
DPSE							.12670	
DMOC								1.00000
MEOC								2.05000
DPOC								.12670
LHAYUSE	1.00000-	1.00000-	1.00000-	1.00000-	1.00000-	1.00000-	1.00000-	1.00000-

Table 21. Continued

	LHAYNO	LHAYDE	MHAY	LEUCAENA	RYEGRASS	RYESESA	SUCANE	SUCANE2
DPJMAX	.00130-	.00130-	171.34850-	172.71000-	184 74000-	15.92000	457.88000-	160 60000-
DMJA				850 00000				
MEJA				2312 0000				
DPJA				103.40000				
DMFE				800 00000				
MEFE				2176 0000				
DPFE				97 30000				
DMMA				750 00000				
MEMA				2040 0000				
DPMA				91.20000				
DMAP			471.00000	750 00000				
MEAP			1064 0000	2040 0000				
DPAP			24 70000	91.20000				
DMMY			176 00000	700 00000				
MEMY			398.00000	1904 0000				
DPMY			9.20000	85.10000				
DMJN			101.00000	600 00000	476 00000		1000 0000	800 00000
MEJN			190 00000	1632.0000	1376 0000		2510 0000	2008 0000
DPJN			1.60000	73 00000	75.70000		1.00000	.80000
DMJU			59.00000	400 00000	940.00000		3000 0000	2000 0000
MEJU			111.00000	1088 0000	2832 0000		7530 0000	5020 0000
DPJU			.90000	38 90000	146 90000		3.00000	2 00000
DMAG			101.00000	400 00000	840 00000		3000 0000	2500 0000
MEAG			190.00000	1088.0000	2304 0000		7530 0000	6275.0000
DPAG			1.60000	38 90000	118.50000		3 00000	2 50000
DMSE			252.00000	500 00000	504 00000		3000 0000	2500 0000
MESE			474.00000	1360 0000	1245 0000		7530 0000	6275 0000
DPSE			16 40000	48 70000	62.70000		3.00000	2.50000
DMOC			647 00000	600 00000			1000 0000	1000 0000
MEOC			1216.0000	1632.0000			2510 0000	2510 0000
DPOC			42 20000	73 00000			1.00000	1 00000
DMNO	1.00000		1104 0000	800 00000				
MENO	2.05000		2495 0000	2176 0000				
DPNO	.12670		72.10000	97.30000				
DMDE		1 00000	1381.0000	850 00000				
MEDE		2.05000	3121.0000	2312 0000				
DPDE		.12670	90.20000	103 40000				
TRSUCA2							1.00000	1 00000-
TRSUCA3								1 00000
HAYUSE			4020 0000					
LHAYUSE	1 00000-	1.00000-						
HAYMAKE			4.02000					
HLAND			1.00000					
PLAND			1.00000	1 00000				
CLAND							1.00000	1 00000
IRRLAND					1 00000			
TRPGSEED					300 00000	100 00000-		
LEUCALLD				1 00000				

Table 21. Continued

	SUCANE3	GRSTYLD	HAYSTY1	HAYSTY2	FBRA	RIPAST	DEFEBRA	MIXPAST
GRJMAX	128.32000-	104.45000-	175.36000-	200.69000-	70.26000-	18.20000-	70.26000-	107.36000-
DMJA		645.00000			1417.0000		1417.0000	1660.0000
MEJA		1322.0000			3202.0000		3202.0000	3797.0000
DPJA		82.30000			92.50000		92.50000	109.70000
DMFE		968.00000			1210.0000			1420.0000
MEFE		1984.0000			2735.0000			3209.0000
DPFE		123.50000			79.00000			92.70000
DMMA					874.00000			1270.0000
MEMA					1975.0000			2870.0000
DPMA					45.90000			71.10000
DMAP					471.00000			700.00000
MEAP					1064.0000			1582.0000
DPAP					24.70000			39.20000
DMMY					176.00000			400.00000
MEMY					398.00000			904.00000
DPMY					9.20000			22.40000
DMJN	600.00000				101.00000	500.00000	374.00000	440.00000
MEJN	1506.0000				190.00000	935.00000	703.00000	827.00000
DPJN	.60000				1.60000	13.10000	10.10000	10.00000
DMJL	1000.0000	317.00000	317.00000	317.00000	59.00000	1000.0000	878.00000	390.00000
MEJL	2510.0000	650.00000	650.00000	650.00000	111.00000	1870.0000	1651.0000	733.00000
DPJL	1.00000	25.20000	25.20000	25.20000	.90000	26.20000	16.90000	8.90000
DMAG	1500.0000	317.00000	317.00000	317.00000	101.00000	1000.0000	920.00000	110.00000
MEAG	3765.0000	650.00000	650.00000	650.00000	190.00000	1870.0000	1730.0000	207.00000
DPAG	1.50000	25.20000	25.20000	25.20000	1.60000	26.20000	13.60000	2.50000
DMSE	1500.0000	158.00000	158.00000	158.00000	252.00000	500.00000	798.00000	430.00000
MESE	3765.0000	324.00000	324.00000	324.00000	474.00000	935.00000	1501.0000	808.00000
DPSE	1.50000	12.60000	12.60000	12.60000	16.40000	13.10000	16.00000	13.20000
DMOC	1000.0000				647.00000		920.00000	650.00000
MEOC	2510.0000				1216.0000		1730.0000	1222.0000
DPOC	1.00000				42.20000		52.30000	36.40000
DMNO		720.00000			1104.0000		1104.0000	1170.0000
MENO		1476.0000			2495.0000		2495.0000	2644.0000
DPNO		91.90000			72.10000		72.10000	76.40000
DMDE		1080.0000			1381.0000		1381.0000	1490.0000
MEDE		2214.0000			3121.0000		3121.0000	3367.0000
DPDE		137.80000			90.20000		90.20000	97.30000
TRSUGA3	1.00000-							
HAYUSE			2500.0000					
CHAYUSE				3413.0000				
HAYMAKE			2.50000	3.41300				
PLAND		1.00000	1.00000	1.00000	1.00000		1.00000	1.00000
CLAND	1.00000					1.00000		
RICEPA						1.00000		

Table 21. Continued

	COYLD1	COYLD2	COYLD3	MUREQ	HF4SALE*	STRUSA**	CUBUSA	CUCOSA
DR.JMAX	80.75000-	158.49000-	306.72000-		161.61000	251.34000	230.34000	170.18000
DMJA	501.00000	784.00000	1146.0000	289.27000-				
MEJA	952.00000	1694.0000	2360.0000	429.88000-				
DPJA	24.00000	56.00000	67.00000	8.10000-				
DMFE	478.00000	919.00000	1129.0000	289.65000-				
MEFE	908.00000	1294.0000	2308.0000	430.07000-				
DPFE	23.00000	43.00000	65.00000	8.11000-				
DMMA	540.00000	633.00000	1221.0000	290.00000-				
MEMA	1026.0000	1367.0000	2516.0000	430.25000-				
DPMA	26.00000	46.00000	93.00000	8.12000-				
DMAP	519.00000	781.00000	1236.0000	290.34000-				
MEAP	924.00000	1538.0000	2374.0000	430.42000-				
DPAP	11.00000	34.00000	66.00000	8.13000-				
DMMY	314.00000	601.00000	846.00000	290.66000-				
MEMY	559.00000	1303.0000	1625.0000	430.58000-				
DPMY	7.00000	33.00000	45.00000	8.14000-				
DMJN	298.00000	333.00000	367.00000	290.96000-				
MEJN	370.00000	656.00000	704.00000	430.73000-				
DPJN	5.00000	17.00000	19.00000	8.15000-				
DMJL	216.00000	217.00000	316.00000	291.24000-				
MEJL	394.00000	428.00000	607.00000	430.87000-				
DPJL	5.00000	11.00000	17.00000	8.15000-				
DMAG	229.00000	272.00000	390.00000	291.50000-				
MEAG	407.00000	536.00000	748.00000	431.01000-				
DPAG	5.00000	14.00000	21.00000	8.16000-				
DMSE	168.00000	299.00000	229.00000	287.52000-				
MESE	300.00000	410.00000	439.00000	428.99000-				
DPSE	4.00000	10.00000	12.00000	8.05000-				
DMOC	250.00000	365.00000	368.00000	288.00000-				
MEOC	475.00000	654.00000	759.00000	429.23000-				
DPOC	12.00000	22.00000	28.00000	8.06000-				
DMNO	238.00000	544.00000	626.00000	288.45000-				
MENO	453.00000	1179.0000	1293.0000	429.46000-				
DPNO	11.00000	34.00000	48.00000	8.08000-				
DMDE	365.00000	859.00000	1071.0000	288.87000-				
MEDE	693.00000	1921.0000	2206.0000	429.67000-				
DPDE	18.00000	64.00000	81.00000	8.09000-				
PLAND	1.00000	1.00000	1.00000					
AU				1.00000				
LAOPCOW				23450-				
DRYPRCOW				.23450-				
BULLS				02345-				
CALVES				05393-				
HF2				05215-				
HF3				07588-				
HF4				04877-				
ST2				05215-				
ST3				07588-				
ST4				09877				
SST4				09877-		1.00000		
HEIF				04249-	1.00000			
CUBULLS				00539-			1.00000	
CUCOWS				03752-				1.00000

* Heifer sale may occur at 20, 32 and 44 months of age.

** Steer sale may occur at 8, 20 32 and 44 months of age.

Table 21. Continued

	LPCOW	LGCOW	DFCOW	BURQ	CARQ	HF2RO50*	HF3RO50*	HF4RO50*
DMJA				37.93000-		10.27000	37.27000	41.27000
MEJA	204.87000-	200.93000-	3.94000-	55.48000		4.12000-	57.82000-	47.52000-
DPJA	5.24000-	5.24000-		2.31000-		8.92000-	5.13000-	3.68000-
DMFE				6.35000-		37.65000	28.35000	65.65000
MEFE	207.68000-	200.99000-	6.69000-	51.67000		38.07000	73.93000-	1.13000-
DPFE	5.25000-	5.25000-		1.30000-		6.45000-	4.96000-	2.53000-
DMMA				37.20000-		11.90000	.70000	4.80000
MEMA	212.41000-	201.04000-	11.37000-	55.85000		3.75000-	127.75000-	109.15000-
DPMA	5.24000-	5.26000-		2.29000-		8.00000-	6.35000-	4.28000-
DMAP				26.46000-		27.66000-	10.34000	14.34000
MEAP			19.34000-	68.02000		277.58000-	109.58000-	91.57000-
DPAP				1.95000-		11.07000-	5.87000-	3.87000-
DMMY				36.54000-		37.94000-	1.34000	5.40000
MEMY			32.28000-	56.18000		301.02000-	127.42000-	108.82000-
DPMY				2.27000-		11.70000-	.33000-	4.26000-
DMJN				25.84000-		110.94000	106.56000	77.96000
MEJN			55.90000-	68.33000		136.73000	162.73000	193.73000
DPJN				1.93000-		.95000	1.75000	2.45000
DMJU				33.96000-		105.24000	101.14000	71.14000
MEJU			95.03000-	56.47000		127.67000	153.97000	185.97000
DPJU				2.26000-		.71000	1.54000	2.26000
DMAG				35.70000-		105.50000	101.40000	71.40000
MEAG			161.56000-	56.61000		127.21000	154.11000	186.11000
DPAG				2.25000-		.72000	1.55000	2.27000
DMSE				29.28000-		107.52000	103.52000	74.52000
MESE	200.67000-	200.67000-		66.59000		134.99000	160.99000	191.99000
DPSE	5.18000-	5.18000-		2.03000-		.85000	1.65000	2.35000
DMOC				39.20000-		64.80000	44.10000	40.00000
MEOC	200.74000-	200.74000-		54.83000-		82.03000	58.47000-	48.17000-
DPOC	5.20000-	5.20000-		2.35000-		5.58000-	5.17000-	3.72000-
DMNO				28.35000-		72.45000	52.45000	48.45000
MENO	200.81000-	200.81000-		67.06000		93.46000	42.94000-	32.94000-
DPNO	5.21000-	5.21000-		2.00000-		5.12000-	4.72000-	3.32000-
DMDE				38.33000-		65.67000	44.97000	40.87000
MEDE	203.18000-	200.87000-	2.31000-	55.27000		82.47000	58.03000-	47.73000-
DPDE	5.23000-	5.23000-		2.32000-		5.55000-	5.14000-	3.69000-
LAPRECOW	1.00000							
LAGPCOW		1.00000						
DRYPRCOW			1.00000					
BULLS				1.00000				
CALVES					1.00000			
HF2						1.00000		
HF3							1.00000	
HF4								1.00000

* Additional requirements for heifers vary according to assumptions and calving rates considered in the analysis.

Table 21. Continued

	ST2R050*	ST3R050*	ST4R050*	CASAP	CASRO	SACARO	RICE	MRISTRAW
OBJMAX				367 94000-	4 52000-	19 64000	27 61000	
DMJA	41.27000	13 17000	8.33000-					
MEJA	45 65000	157 02000-	137 42000-					
DPJA	9 82000-	7.19000-	4 92000-					
DMFE	23 98000-	37 65000	29.85000					
MEFE	281 13000-	133 03000-	82.33000-					
DPFE	11 45000-	5 70000-	3 65000-					
DMMA	57 20000-	51 00000-	7 60000-					
MEMA	331 75000-	243 45000-	137 05000-					
DPMA	13 58500-	8 41000-	4 90000-					
DMAP	45 64000-	39 66000-	27 66000-					
MEAP	306.18000-	221 58000-	154 58000-					
DPAP	12 87000-	7 87000-	4.77000-					
DMMY	56 54000-	50 34000-	37 74000-					200 00000
MEMY	331 42000-	243 12000-	173 92000-					374 00000
DPMY	13 56000-	6 39000-	5 19000-					4 80000
DMJN	95 96000	66 96000	58.46000	524 00000	150 00000			200 00000
MEJN	130.73000	126 73000	145 73000	1383 0000	522.00000			374 00000
DPJN	95000	95000	1.25000	59 70000				4 80000
DMJU	89 84000	54 74000	50.94000	699 00000	200 00000			200 00000
MEJU	120 87000	116 77000	136.37000	1645 0000	696 00000			374 00000
DPJU	71000	71000	1.02000	71 60000				4 80000
DMAG	99 90000	60 00000	51.20000	874 00000	250 00000			
MEAG	121.01000	116 91000	136 51000	2306.0000	870.00000			
DPAG	72000	72000	1.03000	90 60000				
DMSE	92 52000	61.52000	55.02000	874 00000	250 00000			
MESE	128.99000	124 99000	143.99000	2306 0000	870 00000			
DPSE	85000	85000	1.15000	90 60000				
DMOC	40 00000	8 90000	24.50000	524 00000	150 00000			
MEOC	153 57000-	157.67000-	76.07000-	1384 0000	522.00000			
DPOC	9 92000-	7 23000-	4 34000-	53.70000				
DMNO	48.45000	18 45000	33 45000					
MENO	134 54000-	138 54000-	59 54000-					
DPNO	9 32000-	6 72000-	3 92000-					
DMDE	40 87000	9 77000	25.37000					
MEDE	153.13000-	157.23000-	75 63000-					
DPDE	9 89000-	7.20000-	4.31000-					
CLAND				1 00000			1 00000	
CASROOTS				7420 0000	1000 0000-	1000 0000-		
RSTRAW							1500 000	1000 0000-
ST2	1 00000							
ST3		1 00000						
ST4			1 00000					

* Additional requirements for steers vary according to assumptions and calving rates considered in the analysis.

Table 21. Continued

	HFRQ2*	HFRQ3*	STRQ2*	STRQ3*	HFRQ290**	STRQ290**
DMJA	98.73000-	70.73000-	98.73000-	51.73000-	70.73000-	136.00000-
MEJA	450.12000-	243.42000-	320.12000-	190.12000-	243.42000-	534.70000-
DPJA	14.84000-	8.43000-	13.60000-	7.61000-	8.43000-	16.70000-
DMFE	60.35000-	69.05000-	60.35000-	65.05000-	69.05000-	169.50000-
MEFE	365.93000-	185.93000-	247.93000-	177.93000-	185.93000-	574.50000-
DPFE	12.61000-	6.45000-	11.49000-	6.45000-	6.45000-	14.30000-
DMMA	98.00000-	107.30000-	98.00000-	103.30000-	137.30000-	218.40000-
MEMA	449.75000-	251.05000-	319.75000-	243.05000-	257.05000-	662.00000-
DPMA	14.82000-	8.00000-	13.58000-	8.00000-	8.00000-	17.68000-
DMAP	85.66000-	93.66000-	85.66000-	99.66000	93.66000-	273.70000-
MEAP	421.56000-	229.58000-	295.58000-	221.58000-	229.59000-	803.20000-
DPAP	14.07000-	7.47000-	12.87000-	7.47000-	7.47000-	18.27000-
DMMY	97.34000-	106.60000-	97.34000-	133.34000-	205.30000-	292.10000-
MEMY	449.42000-	250.72000-	319.42000-	321.42000-	567.60000-	844.10000-
DPMY	14.60000-	7.98000-	13.56000-	9.22000-	15.46000-	19.16000-
DMJN	64.96000	10.96000	95.96000	5.46000	34.00000	15.00000
MEJN	82.73000	81.27000-	120.73000	30.73000	42.10000-	87.70000-
DPJN	3.25000-	5.05000-	1.21000-	1.85000-	5.65000-	7.45000-
DMJU	59.24000	1.94000	89.24000	3.46000-	30.80000	6.90000
MEJU	70.87000	98.43000-	110.87000	17.57000	57.70000-	104.90000-
DPJU	3.63000-	5.49000-	1.53000-	2.15000-	6.11000-	8.00000-
DMAG	59.50000	2.20000	89.50000	3.29000-	31.10000	6.30000
MEAG	71.01000	98.29000-	111.01000	17.71000	57.59000-	104.70000-
DPAG	3.62000-	5.48000-	1.52000-	2.14000-	6.10000-	8.00000-
DMSE	61.52000	7.52000	92.52000	2.22000	35.50000	11.50000
MESE	80.99000	83.01000-	118.99000	28.95000	43.80000-	89.40000-
DPSE	3.35000-	5.15000-	1.31000-	1.95000-	5.75000-	7.55000-
DMOC	8.00000	72.00000-	2.00000	53.00000-	4.20000-	71.60000-
MEOC	152.77000-	244.07000-	128.77000-	190.77000-	172.80000-	407.20000-
DPOC	9.92000-	8.47000-	9.30000-	7.65000-	15.54000-	14.84000-
DMNO	18.45000	59.55000-	12.45000	42.25000-	56.50000-	59.50000-
MENO	134.54000-	222.54000-	110.54000-	170.54000-	340.30000-	379.90000-
DPNO	9.32000-	7.92000-	8.72000-	7.12000-	13.52000-	14.10000-
DMDE	8.87000	71.13000-	2.87000	52.13000-	47.60000-	137.00000-
MEDE	152.33000-	243.63000-	128.33000-	190.33000-	365.80000-	536.70000-
DPDE	9.69000-	8.44000-	9.27000-	7.62000-	14.21000-	16.70000-

* Additional requirements for heifers and steers under the calving rates of 70 and 80%.

** Additional requirements for heifers and steers under the calving rate of 90%.

Table 22. Rates assumed for calculating herd composition under different calving rates.

	Calving rates (%)				
	50	60	70	80	90
Mortality (%)					
Cows	4.00	4.00	3.00	2.00	2.00
Bulls	2.00	2.00	2.00	2.00	2.00
Other animals					
0-8 months	8.00	7.00	6.00	5.00	4.00
8-20 "	3.30	3.25	3.20	3.16	3.00
20-32 "	3.00	2.70	2.35	2.17	2.00
32-44 "	2.40	2.20			
44-56 "	2.00	2.00			
Culled animals					
Cow (%)	12	15	18	20	22
Bulls (%)	25	25	25	25	25
Ratio:					
Bull:cows	1:25	1:25	1:20	1:20	1:20

Table 23. Herd structure and animals available for sale (No. and AU) under a calving rate of 50% with steers sold at varying ages.

	Sale ages of steers (months)							
	8		20		32		44	
	No.	AU	No.	AU	No.	AU	No.	AU
Herd structure:								
Lactating pregnant cows	---	---	---	---	---	---	---	---
Lactating open cows	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Dry pregnant cows	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Bulls	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00
Calves from 0-8 months	46.00	11.50	46.00	11.50	46.00	11.50	46.00	11.50
Other animals:								
from 8-20 months	22.24	11.12	44.48	22.24	44.48	22.24	44.48	22.24
from 20-32 months	21.57	16.18	21.57	16.18	43.14	32.36	43.14	32.36
from 32-44 months	21.06	21.06	21.06	21.06	21.06	21.06	42.12	42.12
Total	214.87	164.86	237.11	175.98	258.68	192.16	279.74	213.22
Animals for sale:								
Steers with 8 months	23.00	5.75						
Steers with 20 months			22.24	11.12				
Steers with 32 months					21.57	16.18		
Steers with 44 months							21.06	21.06
Heifers with 44 months	9.06	9.06	9.06	9.06	9.06	9.06	9.06	9.06
Culled cows	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Culled bulls	1.00	1.15	1.00	1.15	1.00	1.15	1.00	1.15
Total	41.06	23.96	40.30	29.33	39.63	34.39	39.12	39.27

Table 24. Herd composition and sale coefficients per AU, under a calving rate of 50% with steers sold at varying ages.

	Sale ages of steers (months)			
	8	20	32	44
Herd coefficients:				
Lactating pregnant cow	0	0	0	0
Lactating open cow	0.30329	0.28412	0.26020	0.23450
Dry pregnant cow	0.30329	0.28412	0.26020	0.23450
Bull	0.03033	0.02841	0.02602	0.02345
Calf	0.06976	0.06535	0.05985	0.05393
Heifer approaching two	0.06745	0.06319	0.05787	0.05215
Heifer approaching three	0.09814	0.09194	0.08420	0.07589
Heifer approaching four	0.12774	0.11967	0.10960	0.09877
Steer approaching two		0.06319	0.05787	0.05215
Steer approaching three			0.08420	0.07589
Steer approaching four				0.09877
Sale coefficients				
Heifers (44 months)	0.05496	0.05148	0.04715	0.04249
Weaned steers	0.03488			
Steers approaching two		0.06319		
Steers approaching three			0.08420	
Steers approaching four				0.09877
Culled bulls	0.00698	0.00653	0.00598	0.00539
Culled cows	0.04853	0.04546	0.04163	0.03752

Table 25. Herd structure and animals available for sale (No. and AU) under a calving rate of 60% with steers sold at varying ages.

	Sale ages of steers (months)							
	8		20		32		44	
	No.	AU	No.	AU	No.	AU	No.	AU
Herd structure:								
Lactating pregnant cows	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Lactating open cows	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Dry pregnant cows	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
Bulls	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00
Calves from 0-8 months	55.80	13.95	55.80	13.95	55.80	13.95	55.80	13.95
Other animals:								
from 8-20 months	26.99	13.50	53.98	26.99	53.98	26.99	53.98	26.99
from 20-32 months	26.26	19.70	26.26	19.70	52.52	39.39	52.52	39.39
from 32-44 months	25.68	25.68	25.68	25.68	25.68	25.68	51.10	51.10
Total	238.73	177.83	265.72	191.32	291.98	211.08	317.40	236.43
Animals for sale:								
Steers with 8 months	27.90	6.98						
Steers with 20 months			26.99	13.50				
Steers with 32 months					26.26	19.70		
Steers with 44 months							25.55	25.55
Heifers with 44 months	10.55	10.55	10.55	10.55	10.55	10.55	10.55	10.55
Culled cows	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
Culled bulls	1.00	1.15	1.00	1.15	1.00	1.15	1.00	1.15
Total	50.45	29.70	49.54	36.20	48.81	42.40	48.10	48.25

Table 26. Herd composition and sale coefficients per AU, under a calving rate of 60% with steers sold at varying ages.

	Sale ages of steers (months)			
	8	20	32	44
Herd coefficients:				
Lactating pregnant cow	0.11247	0.10454	0.09478	0.08459
Lactating open cow	0.22493	0.20907	0.18956	0.16918
Dry pregnant cow	0.22493	0.20907	0.18956	0.16918
Bull	0.02812	0.02613	0.02370	0.02115
Calf	0.07845	0.07291	0.06611	0.05900
Heifer approaching two	0.07591	0.07054	0.06395	0.05708
Heifer approaching three	0.11078	0.10297	0.09334	0.08330
Heifer approaching four	0.14441	0.13422	0.12170	0.10807
Steer approaching two		0.07054	0.06395	0.05708
Steer approaching three			0.09334	0.08330
Steer approaching four				0.10807
Sale coefficients				
Heifer (44 months)	0.05933	0.05514	0.05000	0.04462
Weaned steer	0.03922			
Steer approaching two		0.07054		
Steer approaching three			0.09334	
Steer approaching four				0.10807
Culled bull	0.00647	0.00601	0.00545	0.00486
Culled cow	0.06186	0.05750	0.05213	0.04653

Table 27. Herd structure and animals available for sale (No. and AU) under a calving rate of 70% with steers sold at varying ages.

	Sale ages of steers (months)					
	8		20		32	
	No.	AU	No.	AU	No.	AU
Herd structure:						
Lactating pregnant cows	40.00	40.00	40.00	40.00	40.00	40.00
Lactating open cows	30.00	30.00	30.00	30.00	30.00	30.00
Dry pregnant cows	30.00	30.00	30.00	30.00	30.00	30.00
Bulls	5.00	6.25	5.00	6.25	5.00	6.25
Calves from 0-8 months	65.80	16.45	65.80	16.45	65.80	16.45
Other animals:						
from 8-20 months	31.85	15.93	63.69	31.85	63.69	31.85
from 30-32 months	31.10	23.33	31.10	23.33	62.20	46.65
Total	233.75	161.96	265.59	177.88	296.69	201.20
Animals for sale:						
Steers with 8 months	32.90	8.23				
Steers with 20 months			31.85	15.92		
Steers with 32 months					31.10	23.33
Heifers with 32 months	13.10	9.83	13.10	9.83	13.10	9.83
Culled cows	15.00	15.00	15.00	15.00	15.00	15.00
Culled bulls	1.15	1.44	1.15	1.44	1.15	1.44
Total	62.15	34.50	61.10	42.19	60.35	49.60

Table 28. Herd composition and sale coefficients per AU, under a calving rate of 70% with steers sold at varying ages.

	Sale ages of steers (months)		
	8	20	32
Herd coefficients:			
Lactating pregnant cow	0.24697	0.22487	0.19881
Lactating open cow	0.18523	0.16865	0.14911
Dry pregnant cow	0.18523	0.16865	0.14911
Bull	0.03859	0.03514	0.03106
Calf	0.10157	0.09248	0.08176
Heifer approaching two	0.09836	0.08950	0.07915
Heifer approaching three	0.14405	0.13116	0.11593
Steer approaching two		0.08950	0.07915
Steer approaching three			0.11593
Sale coefficients:			
Heifer (33 months)	0.06066	0.05523	0.04883
Weaned steer	0.05078		
Steer approaching two		0.08950	
Steer approaching three			0.11593
Culled bull	0.00888	0.00808	0.00715
Culled cow	0.09262	0.08433	0.07455

Table 29. Herd structure and animals available for sale (No. and AU) under a calving rate of 80% with steers sold at varying ages.

	Sale ages of steers (months)					
	8		20		32	
	No.	AU	No.	AU	No.	AU
Herd structure:						
Lactating pregnant cows	60.00	60.00	60.00	60.00	60.00	60.00
Lactating open cows	20.00	20.00	20.00	20.00	20.00	20.00
Dry pregnant cows	20.00	20.00	20.00	20.00	20.00	20.00
Bulls	5.00	6.25	5.00	6.25	5.00	6.25
Calves from 0-8 months	76.00	19.00	76.00	19.00	76.00	19.00
Other animals:						
from 8-20 months	36.80	18.40	73.60	36.80	73.60	36.80
from 20-32 months	36.00	27.00	36.00	27.00	72.00	54.00
Total	253.80	170.65	290.60	189.05	326.6	216.05
Animals for sale:						
Steers with 8 months	38.00	9.50				
Steers with 20 months			36.80	18.40		
Steers with 32 months					36.00	27.00
Heifers with 32 months	16.00	12.00	16.00	12.00	16.00	12.00
Culled cows	18.00	18.00	18.00	18.00	18.00	18.00
Culled bulls	1.15	1.44	1.15	1.44	1.15	1.44
Total	73.15	40.94	71.95	49.84	71.15	58.44

Table 30. Herd composition and sale coefficients per AU, under a calving rate of 80% with steers sold at varying ages.

	Sale ages of steers (months)		
	8	20	32
Herd coefficients:			
Lactating pregnant cow	0.35160	0.31738	0.27771
Lactating open cow	0.11720	0.10579	0.09257
Dry pregnant cow	0.11720	0.10579	0.09257
Bull	0.03662	0.03306	0.02893
Calf	0.11134	0.10050	0.08794
Heifer approaching two	0.10782	0.09733	0.08517
Heifer approaching three	0.15822	0.14282	0.12497
Steer approaching two		0.09733	0.08517
Steer approaching three			0.12497
Sale coefficients			
Heifer (32 months)	0.07032	0.06348	0.05554
Weaned steer	0.05567		
Steer approaching two		0.09733	
Steer approaching three			0.12497
Culled bull	0.00843	0.00761	0.00666
Culled cow	0.10548	0.09521	0.08331

Table 31. Herd structure and animals available for sale (No. and AU) under a calving rate of 90% with steers sold at varying ages.

	Sale ages of steers (months)			
	8		20	
	No.	AU	No.	AU
Herd structure:				
Lactating pregnant cows	80.00	80.00	80.00	80.00
Lactating open cow	10.00	10.00	10.00	10.00
Dry pregnant cow	10.00	10.00	10.00	10.00
Bull	5.00	6.25	5.00	6.25
Calves from 0-8 months	86.40	21.60	86.40	21.60
Other animals:				
from 8-20 months	41.90	20.95	83.81	41.90
Total	233.30	148.80	275.21	169.75
Animals for sale:				
Steer with 8 months	43.20	10.80		
Steer with 20 months			41.90	20.95
Heifer with 20 months	19.90	9.95	19.90	9.95
Culled cow	20.00	20.00	20.00	20.00
Culled bull	1.15	1.44	1.15	1.44
Total	84.25	42.19	82.95	52.34

Table 32. Herd composition and sale coefficients per AU, under a calving rate of 90% with steers sold at varying ages.

	Sale ages of steers (months)	
	8	20
Herd coefficients:		
Lactating pregnant cow	0.53763	0.47128
Lactating open cow	0.06720	0.05891
Dry pregnant cow	0.06720	0.05891
Bull	0.04200	0.03682
Calf	0.14516	0.12725
Heifer approaching two	0.14079	0.12342
Steer approaching two		0.12342
Sale coefficients		
Heifer (20 months)	0.06687	0.05862
Weaned steer	0.07258	
Steer approaching two		0.12342
Culled bull	0.00966	0.00847
Culled cow	0.13441	0.11782

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BIOGRAPHICAL SKETCH

Euclides Kornelius was born on March 5, 1939, in Joaçaba, Santa Catarina State, Brazil.

In 1965 he entered the Faculdade de Agronomia, Universidade Federal do Rio Grande do Sul, receiving the degree of Engenheiro Agrônomo in 1968.

In 1969 he began a graduate program at the same university in the Department of Soil Science, receiving the master's degree in agriculture in May 1972.

From 1966 to 1972, he worked first as a technician and later as an agronomist in the office of the Secretaria da Agricultura do Estado do Rio Grande do Sul (Pasture and Microbiology Sections). During 1971 and 1972 he served as a professor in the Department of Soil Science at the Faculdade de Agronomia.

In 1973 he was employed as a researcher by the Departamento Nacional de Pesquisa Agropecuária to work in Bahia and Sergipe States.

In 1974 he was hired by the Secretaria da Agricultura from Mato Grosso State to help in the state research program.

In 1975 he joined EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária) and began working on the forage program for the cerrado region at CPAC (Centro de Pesquisa Agropecuária dos Cerrados).

He was granted a scholarship in 1978 from EMBRAPA and matriculated at the University of Florida.

Euclides Kornelius is married to the former Zara Abreu de Souza and is the father of two sons, Alexandre and Ricardo, and one daughter, Cristine.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Gerald O. Mott

Gerald O. Mott, Chairman
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December 1981

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